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CANADA’S INFLUENCE ON FUTURE U.S. OIL SECURITY

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DECLARATION:

I hereby declare that this thesis is my own work, based on the sources and literature listed in the appended bibliography. The thesis as submitted is 218,762 keystrokes long (including spaces), i.e. 100 manuscript pages.

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ABSTRACT

The global supply of oil will closely match the demand for oil over the foreseeable future. The critical role oil plays in national economies, combined with the tight global oil supply, means that oil security is a vital concern for every country, and in particular the United States. The United States currently ranks as the largest oil consumer and oil importer, forcing them to rely on unstable sources of oil. This has resulted in the United States becoming one of the least energy-secure nations in the world. This thesis will evaluate Canada's capacity to improve American oil security to the year 2030. Canadian oil production will increase substantially in the next 20 years with most of the growth in output coming from the "oil sands". The majority of this future oil production will be exported to the United States and by 2030 Canadian oil imports will account for a large proportion of American total petroleum imports. NAFTA provisions have de-politicized the North American energy trade; this guarantees American access to Canadian oil supplies and ensures that Canada can sell to the American market. This liberal framework, therefore, increases American oil security despite a complete dependence on Canadian oil exports.

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GLOSSARY

b/d	Barrels per day
CAFE	Corporate Average Fuel Economy
CAPP	Canadian Association of Petroleum Producers
CERA	Cambridge Energy Research Associates
CSS	Cyclic Steam Stimulation
EIA	Energy Information Administration
ESIA	Energy and Security Independence Act
EWG	Energy Watch Group
FTA	Free Trade Agreement
Gb	Billion barrels of oil
GHG	Greenhouse Gases
IEA	International Energy Agency
In situ	Oil sands recovery technique, Latin phrase meaning “in place”
Mb/d	Million barrels per day
Mtoe	Million tons of oil equivalent
NAFTA	North American Free Trade Agreement
NEB	National Energy Board
OCS	Outer Continental Shelf
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PADD	Petroleum Administration for Defense Districts
SAGD	Steam Assisted Gravity Drainage
WCSB	Western Canadian Sedimentary Basin

INTRODUCTION

During the 18th century a profound socioeconomic and cultural change began to take place that would irreversibly alter the course of human history. In England a massive migration was underway as ever greater numbers of people began to leave their traditional homes in the countryside in order to gain employment in the growing manufacturing industry. The Industrial Revolution not only changed where people lived and how they made their living, it changed humankinds' conception of how goods were to be produced; no longer would manufactured goods such as textiles be produced on a small scale by individuals. The cottage industry, an informal decentralized network of small independent producers of manufactured goods, came to be replaced by large textile mills and factories which produced goods in vastly larger quantities than was previously thought possible. None of this, however, would have been possible to achieve without the development of the steam engine. Although the steam engine was originally designed to pump water out of the mines, the design evolved throughout the period and came to power an increasingly diverse array of machine tools and eventually was adapted to drive trains and steamboats. In a time where wind and water had been the main sources of energy to power small machines, the development of the steam engine allowed factories to be built further away from rivers since the energy source could now be brought directly to the factory. This new energy source was coal. From this point onwards the secure supply of primary energy sources became an ever increasing concern not only for industry, but for government as well.

The use of coal for energy production had a number of benefits which allowed it to remain the largest source of energy in the world until the mid-20th century; it was cheap, abundant, and locally available. Coal, however, is not without its drawbacks. In addition to being difficult to transport, the negative environmental effects from burning coal are well documented. Despite these drawbacks, coal had no substitute and its use grew unabated. During the Second Industrial Revolution in the mid-19th century, just as coal powered steam engines and steamboats were being produced, exploration for a new energy source was beginning across the ocean from the United Kingdom. In the small American town of Titusville, Pennsylvania a man known as Colonel Drake drilled the first successful oil well in 1858 [Yergin, 1991]. Similar to coal a century earlier, crude oil did not have many uses when it was first commercially produced. Distilled into kerosene, the primary application for oil was as a fuel for lamps. The lamp oil market was very profitable and spawned the creation of some of the first large international corporations such as John D. Rockefeller's Standard Oil of New Jersey, known today as ExxonMobil. The market for oil was just in its infancy and with the advent of the internal combustion engine oil was poised to become the dominant global energy source. In 1916 there were approximately 3.4 million cars registered in the United States, a number that would jump to 23.1 million by the end of the 1920s [Yergin, 1991] and currently stands at close to 250 million [Plunkett Research]. This booming number of vehicles resulted in American oil production rising sharply to meet the increased demand for petroleum products. American oil production increased from 574,000 b/d in 1910, to 1.2 Mb/d in 1920, 4.1 Mb/d in 1940 before peaking at 9.6 Mb/d in 1970 [EIA Petroleum Navigator]. Oil consumption and the demand for motor fuels continued to grow worldwide but the vital importance of oil was truly demonstrated during the rebuilding effort in Europe after the Second World War. Already faced with a shortage of food and raw materials, European countries were confronted with the additional problem of a coal shortage in 1946. The coal shortage forced the closure of a number of power stations across England and industrial production was suspended for three weeks [Yergin, 1991]. To help with the rebuilding of Europe, the United States conceived the aid program known as the Marshall Plan. Armed with billions of American dollars in aid, the European nations solved the problem of inadequate coal supplies by buying larger amounts of crude oil. In addition to fueling cars, planes and ships, power stations, home furnaces and industrial boilers were converted to also burn oil. The importance of this shift to oil cannot be overstated, according to a U.S. government report "without petroleum the Marshall Plan could not have functioned [Yergin, 1991].

Compared to coal, oil has the benefit of being easier to transport and is environmentally cleaner to consume. It was also possible to substitute oil in many of the areas where coal had traditionally been the sole primary energy source. As a result oil consumption rose quickly and by 1950 oil had replaced coal as the main source of America's energy needs, and it continues to be so today. There was, however, one major drawback to oil; domestic production in America was not sufficient to meet demand. Up until the mid-1940s American net crude oil imports were negligible but as consumption increased so did the need for imports. Net imports of crude oil increased from 113,000 barrels per day (b/d) in 1945 and reached 1 Mb/d in 1960 before climbing to over 10 Mb/d in the late 2000s [EIA Petroleum Navigator]. With oil playing an increasingly important role in the American and global economy a new concern quickly emerged; oil security. In general oil security refers to the stability and reliability of oil supplies. The potential threats, however, differ for oil producing and oil consuming nations. Oil producing nations must ensure not only that their oil facilities can reliably produce oil but that the oil can also be brought to market, either domestically or internationally. The most important factors when assessing the oil security of a producing nation is the domestic political situation, the ability to safely transport oil, and production and refining capacities. There are several issues in particular for which oil producing nations must prepare; oil facilities and pipelines face threats from potential terrorist attacks in addition to damage from severe weather events such as Hurricane Katrina in 2005. Oil production and oil exports are sometimes affected by government interference, as is evident in Venezuela. During Hugo Chavez's presidency the Venezuelan oil industry has been nationalized and the state oil company, PDVSA, subsequently had its role expanded to include the funding of social programs. PDVSA is required to spend at least ten percent of its investment budget on social projects, such as building free medical centers and selling discounted food [Alvarez, 2009]. This requirement has shifted focus and investments away from the company's core competency, oil production. As a result Venezuela's oil production has decreased 23% between 2000 and 2008 [EIA International Energy Statistics], despite having some of the world's largest oil reserves.

For oil consuming countries oil security refers to the level of security regarding its consumption pattern. Total production and refining levels are again important factors, in addition to the level of net oil imports and the source countries of imports. The greatest dangers for oil consuming countries have to do with transportation and geopolitics. Oil shipments en route to their final destination have come under greater threat recently as oil tankers have been targeted by pirates in the Gulf of Eden and pipelines have been threatened by terrorist bombings in many regions of the world. Furthermore, unlike other commodities or traded goods, the purchasing of oil from foreign nations is more than a simple market transaction. Politics are often intertwined with the oil industry and, as such, importing countries face the risk of being targets of the "oil weapon"; the intentional withholding of oil supplies. The realization that oil and energy supplies are critically important economic factors has led several producing countries to use their energy resources as tools of power in a realist framework. Chapter 1 describes the manners in which Middle Eastern and North African countries have attempted to use the oil weapon in an attempt to influence international positions *vis-à-vis* Israel and the long-term response of Western countries to the embargo. Russia is yet another country that has been using energy power to maintain influence in world affairs through supply disruptions. In both cases it will be shown that the realist approach has actually harmed the actor by creating distrust among the countries affected by the supply interruptions. Instead of building closer relationships to avoid future supply interruptions, affected countries will seek other sources of energy supplies, try to limit the growth of energy consumption, and seek other methods to limit the leverage of the producing countries. Contrary to the negative consequences from the realist strategy, the neoliberal American-Canadian approach to energy trade has fostered greater trust and cooperation between the two countries. With Canada poised to increase oil production over the coming decades the United States will seek to increase their import dependence on Canada knowing that supply agreements are protected by the North American Free Trade Agreement (NAFTA). The United States is currently one of the least energy-secure nations in the world, however, increasing dependence on Canada will improve their oil supply security.

Before beginning an examination of the oil security of Canada and the United States it is important to undertake a detailed outlook of the global oil industry as we move towards the year 2030. Whether the world will face an oil glut similar to the situation in the 1950s and 1960s, or an oil shortage will undoubtedly have an impact on all nations, Canada and the United States included. In the case of a global surplus in oil supplies, oil security of individual nations would be improved because oil producing nations would aggressively seeking markets in which to sell their oil. Conversely, in the event of a global oil shortage the oil security of consuming nations would be negatively impacted as nations compete against one another in an attempt to secure oil supplies. The coercive power from the threat or imposition of an oil embargo upon oil consuming nations is also much greater in the event of an oil supply shortage due to the fact that it is nearly impossible to substitute oil with another energy source in the short-term. As a non-renewable natural resource it is clear that oil reserves have a limited lifespan and several authors argue that the world has already passed the point of peak oil production. However many reputable organizations, among them the International Energy Agency (IEA), Cambridge Energy Research Associates (CERA) and the Organization of Petroleum Exporting Countries (OPEC) agree that remaining oil reserves are more than able to support continued growth in oil production so long as the necessary investments are made in upstream and downstream facilities. Chapter 2 will critically analyze the literature concerning peak oil theory before determining the probable level of oil consumption to the year 2030. It appears most likely that an oil crisis is not yet at hand, nevertheless global spare capacity will remain close to zero and supply will closely match demand without much margin for manoeuvring. Growth in oil demand from China, India and other developing nations will increase more than in the industrial countries and will intensify the competition for oil supplies.

Global oil production is but one factor determining the oil security of Canada and the United States, what must also be determined is the future of each country's domestic oil industry. As the birthplace of the commercial oil industry, the United States has historically been one of the largest oil producers in the world. Since 1970 the United States has faced the unenviable problem of a simultaneous decline in oil production and an increase in oil consumption, leading the country to assume the position as the world's largest importer of oil by a wide margin. American oil imports have risen from 6.26 Mb/d in 1973 to a staggering 12.91 Mb/d in 2008, more than the total consumption of the world's second largest consumer, China [EIA Petroleum Navigator]. With oil imports making up two-thirds of total oil consumption, the United States is forced to rely on a number of nations to satisfy its oil demand. Relying on unstable nations such as Venezuela, Nigeria, and Iraq for vital oil supplies, in addition to the overall level of imports, has led the Energy Security News to rank the United States as the least secure nation in term of oil supply security [DeBard, 2009]. There is some hope on the horizon to improve their precarious situation however. Domestic oil production, in decline since 1970, could receive a boost if offshore oil production is allowed to begin following the removal of offshore drilling bans in 2008. Oil consumption will also halt its historical rise due to the Energy Independence and Security Act of 2007, legislation which promotes greater energy efficiency and the use of biofuels and renewable energy. Furthermore, the United States will be able to import greater volumes of oil from Canada enabling the U.S. to cut its level of dependence on OPEC countries and other nations with whom they have contentious relationships. These issues will be expanded on in Chapter 3 and will demonstrate that the United States will see its oil supply security improve by 2030.

Canada has been endowed with massive reserves of oil and will significantly increase its oil production over the next 20 years. As such a more detailed look at the Canadian oil industry is essential. Chapter 4 describes the composition of the Canadian oil reserves which are quite unique with both conventional and unconventional sources of oil. The quiet oil giant, Canadian oil reserves are second in size only to Saudi Arabia. Unlike the sweet light crude oil found on the Arabian Peninsula, however, almost the entirety of Canadian oil reserves is trapped in a thick mixture of oil, sand and water. These "oil sands" are located in the Western Canadian province of Alberta and pose a number of challenges. Extracting and refining the oil is much more complicated, expensive and energy intensive compared to conventional crude oil and emits greater levels of greenhouse gases. These are important factors to consider as the issue of climate change continues to become a larger socio-political issue. In order for Canada to become one of the largest oil producers the oil industry will need to improve technology so that extraction from the oil sands can become more efficient and less polluting. As oil production increases it is likely that Canadian oil exports to the United States will also increase. This mutually beneficial arrangement will improve American oil security while providing Canada with a large source of stable income.

CHAPTER 1: INTERNATIONAL RELATIONS AND THE OIL WEAPON

"There is no substitute for energy…The whole edifice of modern life is built upon it. Although energy can be bought and sold like any other commodity, it is not 'just another commodity', but the precondition of all commodities, a basic factor equally with air, water and earth." E.F. Schumacher[1] [Yergin, 1991]

E.F. Schumacher's quote deliberately avoids naming a specific source of energy since the predominant primary source of energy changes over time. From the beginning of the Industrial Revolution until the mid-20th century the world's main source of primary energy came from coal. The importance of coal diminished after oil production spread to the Middle East and North Africa in the mid-20th century. New oil producers such as Saudi Arabia, Kuwait, Iran, and Algeria were eager to reap the financial benefits that came from selling ever greater amounts of crude oil. The combined actions of the new oil producers resulted in an over-supply which drove down the price of oil and made it cheaper than coal. The low cost of crude oil, in addition to the wide array of petroleum products, helped to quickly establish oil as the new dominant source of energy. Although oil will itself be replaced in importance by another source of energy in the future, it remains the most critical source of energy today. In 2007 oil accounted for 42.6% of total global consumption of energy while coal and peat made up just 8.8% of consumption [IEA Key World Stats, 2009]. Oil accounts for an even larger share among industrialized nations; 49.7% of total energy consumption in OECD countries came from oil in 2007 [IEA Key World Stats, 2009]. True to Schumacher's statement, unlike any other commodity, fluctuations in the price of oil can drive economic growth or just as easily start a recession. The implications of this fact differ for individual countries depending whether they are oil producers or oil importers. For many oil producing countries, particularly among developing nations, oil brings "power, influence, significance, and status" [Yergin, 1991] in addition to large revenues. For developing nations, whose opinions are often disregarded in

[1] E.F. Schumacher: Chief Economic Advisor to the United Kindgom National Coal Board 1950-1970

international affairs, oil exports provide a significant source of leverage in order to gain a larger voice in the international community. Several nations, however, have exploited their leverage on the international political scene. Countries belonging to the Organization of Arab Petroleum Exporting Countries (OAPEC) have used the oil weapon several times, most notably in 1973, while Russia has also mixed politics and energy supplies a number of times since the year 2000. The "oil weapon" refers to the deliberate withholding of oil supplies by the producing countries. This economic weapon can be applied in a number of ways, either through a selective embargo against one or more countries or through a cut in overall production levels to create a global shortage of oil. Using energy exports in this manner is an example of a realist framework in international relations. The realist school is characterized by a belief that the international system is in a state of anarchy due to the absence of an international government [Burchill et al, 2005]. In an anarchic environment individual states cannot rely upon other nations for security and therefore "seek to survive under anarchy by maximizing their power relative to other states" [Mearsheimer, 1990]. In this zero-sum game of international politics Mearsheimer believes that states "seek opportunities to weaken potential adversaries and improve their relative power position" [1990]. The critical importance of energy supplies for national economies has been recognized by OAPEC members and Russia who have therefore chosen to increase their relative power positions through their energy exports. OAPEC's goal in instituting the 1973 oil embargo was to force a return of land seized by Israel during the 1967 war, to grant rights to Palestinians and to change the status of Jerusalem [Licklider, 1988]. Russia, meanwhile, has attempted to use the power from energy exports for a number of reasons; as a demonstration of their displeasure over the eastern spread of NATO, to undermine political leaders in neighboring countries and to maintain their sphere of influence. The effectiveness of this realist strategy is debatable. Oil importing nations have not always acquiesced to the demands of the energy exporters. They have instead attempted to maximize their oil security by securing reliable supplies from alternative sources [Yenikeyeff, 2009 and Kramer, 2009] and establishing energy sharing agreements to counteract the threat of an oil embargo. One such agreement was the International Energy Program of 1974 which led to the creation of the International

Energy Agency (IEA). Although the realist strategy is meant to improve the well-being of a country, it appears as though the long-term prospects for energy exporting countries are harmed by espousing the realist framework.

In North America, where the United States is becoming increasingly dependent upon Canada as their largest oil supplier, the energy trade follows a different paradigm. Contrary to the consequences of the realist use of energy power demonstrated by certain Arab countries and Russia, the neo-liberal framework in North America creates greater trust and encourages the United States to increase their reliance on Canada. In general, liberalism promotes market capitalism as the best method to increase the welfare of society [Burchill et al, 2005]. Of particular importance to neo-liberals is the role of free trade between nations. Removing artificial barriers to trade, such as tariffs and quotas, will lower the costs of trade thereby increasing the overall level of trade between partners. This in turn reduces tensions between partners by expanding the range of contacts and levels of understanding [Burchill et al, 2005]. Greater economic collaboration between countries, through free trade and the removal of other barriers to commerce, creates an interdependence which encourages non-military solutions to problems since each country has a "joint stake in each other's peace and prosperity" [Burchill et al, 2005] The European Union is frequently cited as an example of the neoliberal framework, however interdependence between Canada and the United States has increased through their own free trade agreements. Complete removal of tariffs and quotas began with the 1989 signing of the Free Trade Agreement (FTA) and continued under the North American Free Trade Agreement (NAFTA) which also included Mexico. NAFTA has not only deepened the level of economic integration between Canada and the United States but has also regulated the energy trade. As a consequence of these agreements Canadian oil exports have grown tremendously and Canada is now the largest foreign supplier of oil to the U.S. Furthermore, NAFTA ensures that the United States will continue to have access to Canadian oil production in the future. The United States will therefore look for Canadian oil exports to make up a greater share of their total oil imports. Contrary to the experience between Europe and Russia, greater American dependency on Canadian oil imports will actually increase American oil security. Canadian oil imports will displace imports from other regions of the world which are politically and economically volatile and from countries which may not have an interest in American oil security. The benefits from NAFTA are far from one-sided as Canada will be able to reap the economic windfall from selling greater volumes of oil to the United States. This mutually favourable arrangement is far more secure than the unreliable realist framework present in other energy exporting countries.

1.1 The 1956 and 1967 Oil Embargos

Forty years ago the United States was the largest producer of oil in the world, responsible for producing half of the world's crude oil. American production, refining and transportation infrastructure was so advanced that the country enjoyed the luxury of having some spare capacity. In the event of emergency American oil production could be increased to make up for losses in production from other regions, leading the National Security Council to state in 1960 that America was "Europe's principle safety factor in the event of denial of Middle East oil" [Yergin, 1991]. American and Venezuelan shut-in production was deemed sufficient enough to overcome any potential loss, and for a while this was true. The oil weapon was first used during the Suez Crisis in 1956 and then in the Six-Day War of 1967 to little effect as global oil shipments were redirected to embargoed countries to minimize the effects of the supply interruption from the Middle East.

In 1956 British, French and Israeli forces mounted an attack on Egypt in response to Egyptian President Gamal Abdel Nasser's decision to nationalize the Suez Canal. The main objective of the military operation for the European nations was to regain control of the Suez Canal which was a vital transportation route of oil bound for Europe. Originally constructed to shorten the shipping route from Britain to India, the Suez Canal played a much more important role in 1955; two-thirds of Europe's oil passed through the canal [Yergin, 1991]. The strategic importance of the Canal was not lost on Nasser who firmly advocated using the oil weapon. He understood oil meant power because without oil "all the machines and tools of the industrial world are 'mere pieces of iron, rusty, motionless, and lifeless'" [Yergin, 1991]. Israeli forces concentrated on seizing the Sinai Peninsula while the French and English forced advanced to secure the Canal. Nasser managed to sabotage the canal before the Anglo-French forces were able to secure it by sinking heavy ships at the entrance, effectively blocking it off. Saudi Arabia further strained Europe's oil supply by deciding to stop all of their oil exports to France and Britain in retaliation for attacking Egypt. The United States, upset at the attack by their allies, did not initially offer to help ease the oil shortage. By December of 1956, however, it was starting to become clear that Europe was in great need of oil supplies and the United States decided the only course of action was to implement the "Oil Lift". The oil lift required increasing production by utilizing American shut-in capacity in addition to redirecting supplies headed for the U.S. towards Europe. The oil embargo resulted in a total loss of 2 Mb/d [IEA Oil Supply Security, 2007] however the oil lift achieved its goal by covering almost 90% of the lost Middle Eastern supplies [Yergin, 1991]. By the spring of 1957 the Suez Crisis had ended with Egypt once again losing control of the Suez Canal. The Suez Crisis demonstrated that the United States had the capability to subvert attempts by Saudi Arabia at restricting oil supplies; however this was in 1956 when oil only made up 20% of European energy needs [Yergin, 1991]. The industrialized nations were not yet dependent enough on Arab oil imports for Saudi and Egyptian actions to influence them. A more concerted effort by oil producing nations and a higher volume of world oil exports would be needed if the oil weapon were to be effective.

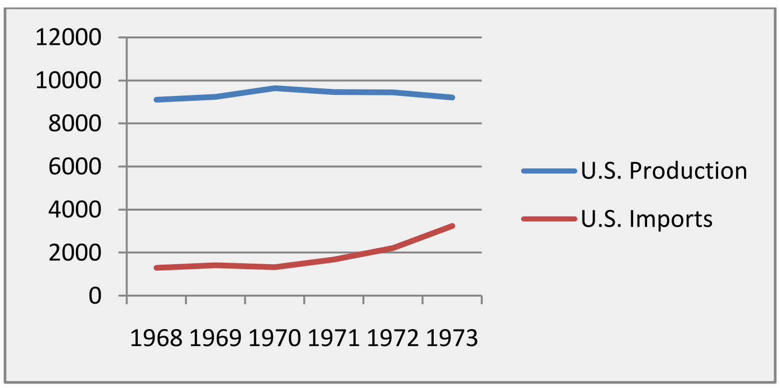
Following the Suez Crisis, the Sinai Peninsula and the Suez Canal were placed under U.N. peacekeeping control. Western countries were relieved to have the canal open once again, however the events of 1956 created greater distrust of Israel and Western nations among the Arab countries. The presence of the U.N. Emergency Force in the Sinai proved to be a temporary solution; in May 1967 Nasser ordered the withdrawal of all U.N. troops from Egypt, blocked all shipping to Israel through the Gulf of Aqaba and positioned Egyptian troops along Israel's border [Yergin, 1991]. With armed forces in Egypt, Syria and Jordan positioning for an apparent attack, Israel decided to act pre-emptively with air strikes on Egyptian targets on June 5th, 1967. The air strikes were impressively successful, so much so that the Arab nations were convinced Israel had direct support from Western nations in the assault. Israel, however, acted alone. In the years leading up to the Six Day War Israel had been training their air force to gain air superiority in the region and their training had been so effective that it "made possible an attack greatly exceeding in intensity what Hussein and Nasser believed possible with the number of aircraft known to be in Israel's inventory" [Daoudi, 1984]. In a meeting of Arab nations in Baghdad on the first day of air strikes it was agreed that Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar, Abu Dhabi, Libya and Algeria would place under embargo any country that was helping Israel. As a result the United States and Great Britain, assumed to have aided Israel in the air raids, and West Germany were denied Arab oil supplies [Daoudi, 1984].

Like the oil embargo in 1956, the 1967 embargo was largely ineffective. The Arab countries had held a number of summits to discuss the actions to be taken and the opinions were severely divided. The oil embargo had been proposed by non oil producing nations Egypt, Syria and Lebanon while the oil producing countries such as Saudi Arabia and Kuwait were not eager participants. Calls by Iraq proposing a full stop to oil production were met with reservations, after all, income from oil production accounted for 97% of Kuwaiti government revenues and 87% of Saudi revenues [Daoudi, 1984]. In spite of disagreements the flow of oil was severely disrupted in the first several days of the war. By the 8th of June, 1967 the flow of Arab oil had been reduced by 60% with an initial loss of 6 Mb/d [Yergin, 1991]. Oil supplies were not only limited as a result of production stoppages but also due to the closing of refineries, pipelines, and the Suez Canal. The embargo remained in place until the 4th Arab Summit Conference in Khartoum, Sudan on August 29th, 1967 where it was agreed to end the embargo in exchange for Saudi, Kuwaiti and Libyan financial aid to Egypt to make-up for Egyptian financial losses from the war. The net result of the embargo was a total halt of oil production in the Arab states for 5 days and a denial of supplies to the U.S., Great Britain and West Germany until September 2, 1967 [Daoudi, 1984]. The embargo caused a logistical nightmare for Europe. Oil supplies had to be diverted away from the Suez and travel around the African continent, but it did not significantly reduce the amount of available oil to the importing countries. The failure of the embargo was a result of several factors but most importantly due to the diversity of supply. Some estimates show the total loss of oil was approximately 2 Mb/d over the course of the embargo [IEA Oil Supply Security, 2007], an amount easily made up from the non-Arab producers. OPEC members Venezuela and Iran did not act with their Arab counterparts, instead choosing to increase their oil production and gain a larger share of the world market. The United States also increased domestic oil production so that the overall loss from the Arab countries was not significant. For the embargo to have been more effective the Saudis, Kuwaitis and Libyans would have had to cut their total production output to create a larger loss of global oil supply. Even a bold action such cutting production would ultimately be self-defeating, however, since there was still a global spare capacity of production. Production cuts would have greatly complicated the world oil market but increased output from the non-Arab producers, in addition to the large stockpiles of oil in Western countries, would have mitigated much of the potential damage. The Arab countries thus risked losing revenues and long-term export market contracts without having anything to show for it. For the embargo to work the Arab countries would have to control a greater amount of world oil production and keep the embargo in place for a longer amount of time. The 1967 embargo did demonstrate, however, that Arab nations were able to work in concert during a time of crisis. The embargo was agreed to shortly after Israeli bombing began and throughout the ordeal the Arab countries did not break ranks. For the oil producing countries, the power of the oil weapon to gain leverage in international affairs, particularly if it were to be applied on a larger scale, was now even more apparent. The experience from 1967 revealed obstacles needed to be overcome in order to successfully use the oil weapon, lessons they applied during the 1973 Yom Kippur War.

1.2 The 1973 Oil Embargo

In the years following the Six-Day War conditions changed in favour of the Arab oil producing countries. World oil consumption continued to increase in spite of the 1967 embargo with Middle Eastern countries responsible for most of the growth in oil output. Particularly notable was the increase in American oil consumption leading up to the 1973 crisis. To satiate demand American production was brought to maximum capacity, by 1970 the spare production capacity had dropped to 1 Mb/d from 4 Mb/d in the late 1960s [Yergin, 1991]. In hindsight we now know that 1970 was when American production peaked at a rate of 9.6 Mb/d [EIA Petroleum Navigator], forcing the government to ease oil import quotas. With its production having peaked, the United States would need to rely on imported oil to supply any growth in consumption. Between 1968 and 1973 American crude oil imports increased more than doubled from 1.2 Mb/d to 3.2 Mb/d [Figure 1, EIA Petroleum Navigator] and imports as a percentage of consumption from rose from 19% to 36% [Yergin, 1991]. The United States was now dependent upon oil imports and vulnerable to fluctuations in the global oil supply market. No longer could American oil production be considered a safety net for Europe.

Figure 1: U.S. Production and Imports of Crude Oil 1968-1973 (thousand barrels per day)



Source: EIA Petroleum Navigator

Growing world oil consumption was a boon for Saudi Arabia. With the largest proven reserves of any country it was an eventuality that Saudi Arabia would become the largest, and therefore most influential, oil producing country. Saudi Arabian oil production increased dramatically, from 1.31 Mb/d in 1960 to 3.8 Mb/d in 1970 to 8.4 Mb/d in 1973 [EIA World Crude Oil Production]. Saudi Arabia produced 13.6 % of the global oil supply in 1973 while the combined production from OPEC accounted for 55.3% [EIA World Crude Oil Production]. The ability of Saudi Arabia and the other Arab oil producing countries to influence the world oil market was now without question, but the idea to use the oil weapon in 1973 did not originate in the Saudi Kingdom. Continued Israeli occupation of land seized during the Six-Day War continued to be a highly contentious problem among many of the Arab countries, and with Egyptian President Anwar Sadat in particular. Sadat succeeded Nasser as

President of Egypt in 1970 and quickly realized that Israeli occupation of the Sinai Peninsula was the ideal issue around which he could gain support domestically, and among other Arab countries, in order to solidify his control over power. Persistent conflict with Israel had not achieved any real gains for Egypt and resulted in the country spending far too much on the military, approximately 20% of GNP [Yergin, 1991]. Sadat believed that in order to end the conflict with Israel he would to achieve more than military and territorial gains; he would also need Western countries to end their tacit support of Israel and increase Western dialogue with Arab countries. To do this he would need Saudi Arabia and the other Arab oil producers to agree to an oil embargo, the one piece of leverage the Arab countries had.

Initially King Faisal was reluctant to support Sadat's plans. Oil exports were rising and the Kingdom was making more money than it had ever thought possible. Experience from the 1967 embargo had shown that an embargo could lead to lost revenue with few concessions being won. Additionally, Saudi Arabia had good relations with the United States and depended upon them for military support. There was very little for Saudi Arabia to gain in terms of international relations from an embargo and they risked antagonizing the United States. King Faisal, however, was faced with domestic threats to his reign in the 1970s which the United States could not resolve. The Arab world was going through a volatile period where leadership was being openly challenged and deposed by nationalist and socialist movements. On the 25th of May, 1969 a bloodless coup led by Colonel Gaafar al-Nimeiry took power from the civilian government of Sudan and installed a socialist system [Hevesi, 2009 and U.S. Department of State: Sudan]. Northeast of Sudan, Libya was also about to experience a change of power. Since gaining independence from Italian colonial control on December 24, 1951 Libya had been a constitutional and hereditary monarchy under the rule of King Idris U.S. Department of State: Libya]. The discovery of large oil reserves in 1959 instantly made Libya a much wealthier country, however wealth was highly concentrated among the elite. The uneven distribution of income along with the rise of socialist ideology created a highly unstable situation for the ruling elite, and on the 1st of September 1969 King Idris was overthrown by 28 year old army colonel Muammar al-Qadhafi [U.S. Department of State: Libya]. Qadhafi sent King Idris to

Egypt in exile and in place of the monarchy Qadhafi installed the Revolutionary Command Council (RCC) whose motto was "freedom, socialism, and unity" [U.S. Department of State: Libya]. Events on the Arabian Peninsula, where fighting in Yemen resulted in the forming of a Marxist republic in 1970, brought the threat of coup in Saudi Arabia even closer. Agreeing to Sadat's plans would enable King Faisal to pacify radical elements within his borders, minimizing terror threats to oil installations and pipelines and preserve the monarchy [Yergin, 1991].

On October 6th, 1973 much of the world was caught off guard as Egypt and Syria began their attack on Israel just as the country was beginning the celebration of Yom Kippur. King Faisal had warned the United States about repercussions from their military and ideological support of Israel however the war had still caught the Americans by surprise [Licklider, 1988]. Once the war began, meetings between the Arab countries were a daily occurrence with the oil weapon as the main topic of discussion. Finally, on October 17th, 1973 the oil ministers had agreed to the framework of the oil embargo. Production would be cut immediately by 5% with an additional cut of 5% every month thereafter until the objectives of the Arab countries were met [Yergin, 1991]. The oil exporters also decided to separate countries into three categories; friendly, neutral and hostile. Friendly countries would not be subjected to any restrictions on imports while neutral countries were subject to the general monthly production cuts. The United States and the Netherlands (later joined by Portugal, South Africa and the former Rhodesia) were classified as hostile states resulting in a complete ban on all Arab oil imports [Yergin, 1991]. The lessons from 1967 had been applied this time around, not only had certain countries been targeted with import restrictions but the production cuts meant the total supply of world oil was much lower. With the global supply of oil closely matching demand, allied nations were no longer able to re-shuffle oil shuffle supplies amongst themselves because the world was facing an actual shortage of supply. The production cuts had a significant secondary benefit by raising the price of oil. Loss of income had made the 1967 embargo less palatable for Saudi Arabia and the other Arab countries but the embargo as it was applied in 1973 had the effect of raising the price of oil fourfold in a very short span of time [Licklider, 1988]. Oil exporting countries were now making more money from selling less oil. Another important difference from the 1967 embargo is that the Arab governments were now seeking political concessions from the Western world, namely; for Israel to return land occupied since the 1967 war, to recognize the rights of Palestinians, and to change the status of Jerusalem [Licklider, 1988]. The oil embargo thrust the Arab nations onto the international political scene. By withholding oil supplies the Western world was forced to listen to the Arab leaders, and possibly even capitulate to their demands. Never before had the industrialized world been held hostage by developing nations, a fact surely enjoyed by the leaders of the Arab oil producing countries.

The embargo outlasted the actual fighting on the ground as war between Israel and Egypt came to an end on October 26th, 1973. Sadat's objectives for war had been achieved as talks between Egypt and Israel, in addition to talks with the United States, took place for the first time in many years. Ending the oil embargo would take more time however, and two months after the imposition of the oil embargo some 4.3 Mb/d had been lost [IEA Oil Supply Security 2007], an amount equal to 14% of internationally traded oil [Yergin, 1991]. International oil companies were trying their best to deal with the embargo by diverting non-Arab sources of oil to embargoed countries in an effort to redistribute oil in the most equitable manner. The efforts of the oil companies resulted in a fairly even shortage of oil in the industrialized world; the total loss of oil to the United States, Western Europe and Japan over the period of the embargo came out to 18%, 16% and 17% respectively [Yergin, 1991]. The oil embargo remained in place until March 1974 when Sadat recommended its end, believing the objectives of the embargo had been met. Whether or not significant concessions were made to the Arab countries is open for debate.

The countries most likely to change their foreign policies in response to the oil embargo would have been the ones most dependent upon the Middle East for their oil imports. European nations were among the countries which leaned heavily on the Arab countries for their oil imports, in the words of French President Georges Pompidou; "We are entirely dependent upon them" [Yergin, 1991]. By mid-November many European countries, including France and Great Britain, began to distance themselves from the United States by publicly stating opposition to America's Middle Eastern foreign policy and claiming to want an increase in dialogue and cooperation with Arab countries. Another country which desperately wanted to avoid a long-term loss of Arab oil was Japan, which similarly issued a pro-Arab statement shortly after the European countries. These countries issued their statements in November and were rewarded for their compliance of Arab requests by being spared from further cutbacks [Yergin,1991]. The impact of these concessions on changing foreign policy, however, was modest at best. Most of the statements were simply rhetoric and it is not evident that concrete foreign policy changes occurred as a result of the oil embargo. Great Britain, for example, had been involved in the drafting of UN Resolution 242 which demanded the return of all land occupied by Israel during the 1967 war [U.N. Security Council Resolution – 1967]. Their stance had therefore not changed since they had already been supporting the Arab cause prior to 1973. If anything, the British position was one of neutrality; during the 1973 war Great Britain placed an arms embargo on Israel as well as Arab countries and once fighting stopped they resumed arms sales to both sides [Licklider, 1988]. Similarly, Japan had also supported Resolution 242 prior to 1973 and had even supported a UN resolution recognizing the rights of Palestinians in 1970 [Licklider, 1988]. The Arab countries further demanded that the Japanese end diplomatic and economic relations with Israel while supplying Arab countries with weaponry [Licklider, 1988], none of which was granted. Japan did not sever ties with Israel and was prohibited to sell weapons due to their post-WWII constitution. The Japanese did, however, agree to give Arab countries economic assistance, promised to start new joint ventures and agreed to bilateral deals [Yergin, 1991]. The United States, subjected to the embargo the longest, did not make any significant concessions either. American plans for a cease-fire and subsequent peace process (including American involvement) was already being prepared before the oil embargo was even declared, and no major shift in American foreign policy has been noted in the Middle East either during the 1973 crisis or in the decades that followed. Finally, despite the oil embargo, the Western world continues it support for Israel with the United States in particular providing large amount of aid in the form of military supplies. Growth of Israeli settlements on Palestinian land is still a highly contentious issue, as is the independence of Palestine. Lasting change, therefore, does not seem to have occurred as a result of the oil weapon.

The Arab countries seem to have gained very little from the oil embargo in term of direct concessions. The largest concessions would have to be the refusal of European Community countries to allow the United States to use their military bases in order to re-supply Israel [Licklider, 1988], a policy which has only been applied during the 1973 war. Despite this apparent lack of tangible results the oil embargo did result in the Middle East gaining international attention. Up until the 1967 and 1973 oil embargos, the Middle East was seen as a source of petroleum for international oil companies to exploit and little else. Foreign oil companies operating in the Arab countries tried their best to dictate price and production levels in order to maximize their profits with little regard to the considerations of the nations within which they had been operating. The oil embargos forced foreign nations to consider Arab views and created an environment where dialogue with Arab leaders was a necessity. Oil gave Arab nations the necessary leverage to become internationally relevant and to no longer be viewed as backwards nations required to do the bidding of Western countries. Unfortunately for the Arab nations, the threat of the oil weapon was so great that Western countries realized they would need to increase cooperation with each other to lessen the leverage Arab countries had gained through their control of oil supplies. This cooperation led to the formation of the International Energy Agency in 1974.

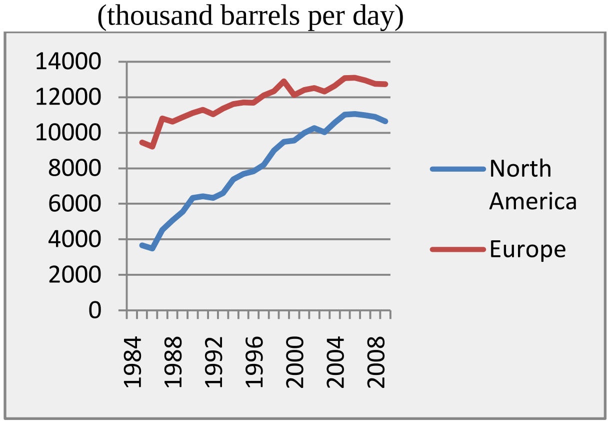
1.3 Response of Western Countries to the Oil Embargos

For Middle Eastern and North African oil producing countries, oil meant a greater degree of power and prestige on the international scene. The industrialized countries of Western Europe and North America were no longer energy independent and relied on Arab and Persian oil imports to maintain their economic growth. This growing reliance on petroleum imports presented the oil producing countries with the means to influence Western foreign policy in the Arab world and to gain a larger voice in international affairs. The producing countries did not count solely on the threat of supply interruptions to increase their profiles but proved they were more than willing to employ the oil weapon, as described above. Although the countries participating in the oil embargo succeeded in gaining international attention, the effectiveness of the oil embargos in imposing profound foreign policy changes is debated. Moreover, the embargo had the lasting effect of highlighting the elevated risk of relying on the unpredictable countries of the Middle East and North Africa. The willingness of oil producing countries to exploit their relative power in energy supplies proved to Western nations that their oil security was in jeopardy and it resulted in efforts to mitigate the threat of future embargos. The industrialized countries realized they would need to attempt energy conservation policies while also improving coordination and cooperation between themselves in the event of a future oil supply interruption. The latter effort resulted in the creation of the International Energy Agency (IEA).

Following the 1973 oil embargo, Western nations realized they would need to limit the growth of energy consumption in order to improve their oil security. During the embargo the United States launched "Project Independence". In the words of President Richard Nixon, the goal was to "ensure that by the end of this decade, Americans will not have to rely on any source of energy beyond our own" [Kraemer, 2006]. Oil imports did initially drop, from 6.25 Mb/d in 1973 to 6.05 Mb/d in 1975, however by 1979 it had risen to 8.45 Mb/d [EIA Petroleum Navigator]. President Jimmy Carter declared energy independence to be a vital issue for national security and in an effort to better manage American energy policy he created the U.S. Department of Energy [Kraemer, 2006]. Oil imports did stay under 6 Mb/d between 1981 and 1985, but over the following 20 years oil imports were forced to increase due to the unabated growth of oil consumption. Between 1985 and 2008 American consumption of crude oil and petroleum products increased from 15.7 Mb/d to 19.5 Mb/d, a 24% increase [EIA Petroleum Navigator]. With domestic oil production in decline, oil imports over the same period of time increased 153%, from 5.1 Mb/d to 12.9 Mb/d (Figure 2 [EIA Petroleum Navigator]). In fact, oil consumption boomed worldwide; global oil consumption increased by 25.7 Mb/d between 1985 and 2008 [EIA International Energy Statistics]. To satiate this growing level of consumption, the world was forced to turn to the largest source of oil, OPEC. As can be seen in Figure 3, OPEC exports of crude oil increased from 12.9 Mb/d in 1986 to just under 25 Mb/d in 2005. Not only were Western nations unable to decrease import reliance, they actually increased OPEC's share of oil supplies and their power over the world oil market.

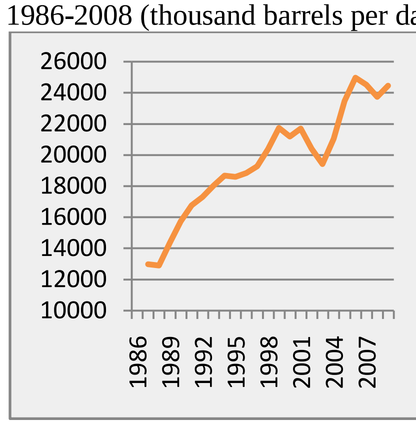
Decreasing OPEC member countries' share of global oil exports proved impossible, but increased cooperation amongst Western countries was achieved. To combat against the oil weapon and potential future oil supply interruptions, the Western countries created the IEA in 1974. Today the main role of the IEA is as an energy policy advisor to its member countries[2], however its formation was initially intended to "co-ordinate measures in times of oil supply emergencies" [IEA: About the IEA]. This function of the IEA is still an important asset to its member countries. The number of oil exporting countries is falling and as production becomes concentrated among fewer countries the world is faced with a greater threat from the oil weapon. Oil embargos are not the only source of potential supply disruptions, however. There is a precarious balance in global supply and demand of oil, even small supply disruptions from wars, piracy at sea, terrorist attacks or catastrophic weather events can have a large economic impact.

Figure 2: Crude Oil Imports (thousand barrels per day)



Source: EIA International Energy Statistics

Figure 3: OPEC crude oil exports 1986-2008 (thousand barrels per day)



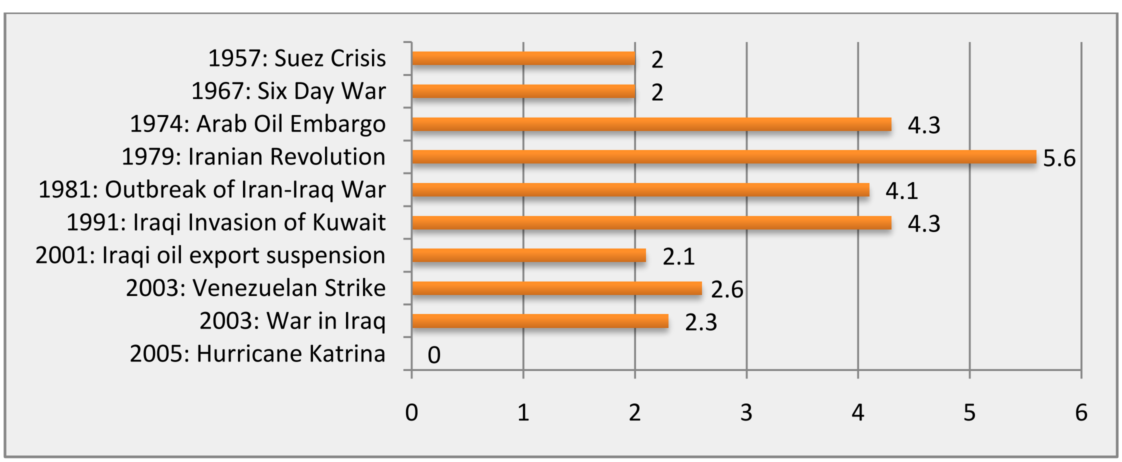
Source: EIA International Energy Statistics

Most of these concerns, however, originate in the Middle East; over the past 40 years 90% of oil lost from supply disruptions has been from Middle Eastern countries (Figure 4 [IEA Oil Supply Security, 2007]). To combat against supply interruptions the IEA uses a number of response measures. The primary defence against a supply interruption is to draw oil from the stockpiles of IEA member countries. Holding

[2] IEA member countries as of 2009: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States

stocks of oil equivalent to 90 days of net imports is a requirement of every non-oil producing IEA member country. Total stocks now stand at 4.1 billion barrels of oil, enough to cover 122 days of net imports [IEA Oil Supply Security, 2007]. Additional oil supplies can also be obtained through an increase in the production of oil. This measure, however, is quite limited among the IEA members who do not have the luxury of spare capacity. In a time of crisis member countries are also asked to reduce their oil consumption through demand restraint and switching to fuels other than oil where possible. Demand restraint works either through public campaigns, such as asking people to drive less and decrease residential heating, or can come through government imposed supply restrictions. Fuel switching is limited in sectors such as transportation (where no alternative to gasoline exists), however some savings can be made in other sectors such as power generation. Austria, for example, can switch 5-7% of their consumption of oil to natural gas while other countries like the Czech Republic and Ireland can switch between 3-10% [IEA Oil Supply Security, 2007]. The ability of the IEA to effectively respond to a supply crisis using these measures was demonstrated in 2005 when oil installations in the Gulf of Mexico were damaged by Hurricane Katrina. The hurricane affected both the oil production and refining capabilities of the United States causing an estimated loss of 1.5 Mb/d. IEA member countries reacted quickly and decisively by brining an additional 60 million barrels of oil to market [IEA World Energy Outlook, 2009]. The response quickly stabilized the world oil market and made up for any loses in the United States.

Figure 4: Loss of Oil from Major Oil Supply Disruptions since 1957 (Mb/d)



Source: IEA Oil Supply Security, 2007

The ability of the IEA response system to deal with a major oil supply disruption can be debated. The daily loss of oil from Hurricane Katrina was less than from any of the other major disruptions listed in Figure 4**,** and lost capacity in the United States was restored as quickly as possible. Another oil embargo would result in a larger loss of oil, and more worryingly would last for an indefinite amount of time. Regardless of the IEA's ability to overcome an oil embargo, the agency still provides a mechanism to at least partially offset the power of the oil weapon. Since its inception the role of the IEA has grown. The agency also tries to enhance the energy security of its members by influencing policy changes, promoting economic development and improving environmental protection. Although attempted energy reforms in the 1970s and 80s were ineffective, new energy reforms appear more promising. Growth in oil consumption among OECD countries by 2030 is predicted to remain relatively flat [OPEC World Oil Outlook, 2009] or even slightly decline [IEA World Energy Outlook, 2009 and EIA International Energy Outlook, 2009] and the IEA member countries' share of global oil consumption will fall to 36% by 2030, much less than the 68% in 1974 when the agency was founded [IEA World Energy Outlook, 2009].

Sadat's goal of initiating dialogue through the 1974 embargo may have had some short-term successes. The long-term view, however, has shown that Western countries have continued to look inward for energy security. Until recently, increasing oil consumption and imports was a necessary evil in order for the industrialized countries to continue their economic growth. This may have increased their reliance on the oil producing countries but it did not diminish American or European support for Israel, nor did it lastingly improve relations with Middle Eastern countries.

1.4 Russia, Oil and Politics

The use of oil supplies in a realist framework can also be observed in modern-day Russia. Following the collapse of the U.S.S.R. it was natural to expect that Russia would undergo many changes in its political and economic structure. Soviet collapse seemed to imply that Western style capitalism had 'won' the battle over communism and resulted in the privatization of many Russian state-owned enterprises for a fraction of their true value. The transition from an authoritarian government and a state-controlled economy was far from smooth. Falling commodity prices, an over-valued ruble and high public debt levels all contributed to the Russian financial crisis of 1998. The financial crisis resulted in $30 billion of foreign currency reserves being used to prop up the ruble, caused most of the big Moscow based banks to fail, GDP to fall by 4.9% and inflation to reach 84% [Pinto et al, 2004]. The financial crisis also saw the end of Boris Yeltsin's Presidency and the rise to power of Vladimir Putin. As President, Putin once again consolidated power in the Kremlin and has used Russia's supplies of oil and natural gas as a tool of power to advance his domestic and international agendas.

The potential threat from Russia is substantial due to their large energy reserves and their current control over Central Asian energy sources. Russia is the second largest producer of both oil and natural gas in the world, with the 8th largest oil reserves and the largest natural gas reserves [EIA International Energy Statistics]. During the Yeltsin administration the federal government did not have great control over the energy industry as more authority was transferred to regional governments. Regional governors were able to influence the domestic energy industry through a principle of "two keys" whereby licenses for the exploration and production of oil and natural gas required approval from both the regional government and the federal Ministry of Natural Resources [Suhomlinova, 2007]. This arrangement favoured smaller, independent energy companies located in energy-rich regions which were given preferential treatment from the local governors. Competition for licenses resulted in an increase in the number of energy companies and by 2000 the Russian oil and gas industry was comprised of 14 large companies and 120 independents [Suhomlinova, 2007]. Putin's administration realized that the "two keys" principle and the vast array of energy companies made it more difficult for the Kremlin to control the energy industry and they set about changing the licensing laws. A license granted to the small company Severnaya Neft in 2001 proved to be the catalyst which enabled change. The oil majors, upset at not being granted the license, did not believe the license was fairly awarded and brought the case to the Russian courts. Although the majors would ultimately be unsuccessful with the court case, they were the primary beneficiaries from the 2004 amendment to Subsoil Law no. 123-FZ which removed the 'two keys' principle and strengthened Federal control over the energy industry [Suhomlinova, 2007]. Without the backing of regional governments, the independent companies were forced to fight for licenses against the energy majors, a battle they were never likely to win. The oil industry went through a great deal of consolidation as the large companies merged and bought out smaller companies leaving the Russian industry with only four oil majors (LUKOIL, Surgutneftegaz, TNK-BP and Rosneft) and 2 regional companies (Tatneft and Bashneft), with the share of output from independent companies falling from 12% in 1999 to 4% in 2005 [Suhomlinova, 2007]. Another important development was the re-nationalization of Gazprom and the acquisition of Yukos subsidiaries by the state-owned Rosneft. Gazprom, privatized in 1993, is a crucial asset for the Russian government because the company is responsible for approximately 20% of the world's natural gas production and partners with Central Asian companies to transport natural gas to Europe and China through Russian territory [Thornton, 2008]. Rosneft is another powerful state-owned energy company. It attained acquired much of the assets from the forced sale of Yukos following the politically motivated arrest of its former chief, Mikhail Khodorkovsky. These two companies, in addition to the other energy companies active in Russia, are more than simply political tools; they also account for 25% of the industrial output, 33% of the federal budget and 50% of hard currency earnings in Russia [Gidadhubli, 2003].

The line between politics and business is highly blurred in Russia. Energy companies, as a direct consequence of their strategic importance in international affairs, are expected to fall in line behind the Kremlin and, where possible, advance the foreign policy aims of the country. When President Putin proposed greater cooperation in the gas sector between Russia and Turkmenistan in 2002 he did not send a government bureaucrat, rather it was Gazprom Chairman Alexei Miller who met with Turkmen President Niyazov [Gidadhubli, 2003]. Energy company executives tempted to oppose the Kremlin are wise to consider the fate of Mikhail Khodorkovsky. Although officially accused of tax evasion and the stealing of state property, many believe the arrest of Russia's richest oligarch has more to do with non-business related issues including his vocal opposition to Putin's politics, financial support of opposition political parties and the purchasing of the Moskovskiye Novosti newspaper [Francetti, 2008 and BBCNews June 16, 2004]. Dissent from many other energy executives is unlikely, however, since many of the executives have close allegiances to the Kremlin and have held important political positions. The governor of the energy rich region of Chukota from 2000 until 2008 was Roman Abramovich [Gidadhubli, 2003] who is better known as the former head of Sibneft (which was sold to Gasprom in 2005). Abramovich was not the only executive to hold governorship; Boris Zolotarev was the Governor of Evenkia in addition to being the Vice-President of the former Yukos oil company [Suhomlinova, 2007]. Other notable examples include Vagit Alekperov (current President of LUKOIL and formerly the Deputy Minister of Oil and Gas) Viktor Chernomyrdin (Chairman of Gazprom, Prime Minister of Russia from 1992-1998 and Ambassador to the Ukraine from 2001-2008 [Suhomlinova, 2007]) and Igor Sechin, (Chairman of Rosneft and the former deputy Chief of Staff for Vladimir Putin [Franchetti, 2008]). Energy executives also represent Russia in non-governmental positions, such as Mikhail Friedman who is the Chairman of the Board for the oil company TNK-BP and serves on the International Advisory Board of the Council of Foreign Relations [CFR, International Advisory Board]. The political appointment of energy executives with close ties to the Kremlin ensures that energy companies will not interfere with government leadership when oil or natural gas are used as political leverage in negotiations. Concretely, this can take the form of agreeing to make investments in pipeline routes through countries friendly with Russia or to cut-off supplies to nations acting contrary to Russian wishes.

Russia has utilized political control over energy supplies by reducing or cutting off supplies to the Ukraine several times over the past four years. The most serious supply disruption came in January 2009 when all natural gas shipments to the Ukraine were stopped due to a dispute over a $600 million debt Ukraine owed to Russia for late payments [Cohen, January 2009]. Fallout from the cut-off extended past Ukrainian borders as Romania, Bulgaria, Greece, Macedonia, Croatia, Serbia and Turkey all experienced a halt in their gas supplies just as winter temperatures were dropping [CBC News, Russia cuts all gas exports to Europe, 2009]. Russia was well aware of the consequences of their actions since Europe receives a quarter of its natural gas imports from Gazprom, with 80% of those imports coming through the Ukraine [Cohen, January 2009]. Russia's drastic actions call into question whether or not the sole issue was debt repayment. The cut-off was a way of creating distrust in Ukraine's pro-Western leaders, President Viktor Yushchenko and Prime Minister Yulia Timoshenko, ahead of 2010 elections while affirming that Ukraine remains in Russia's sphere of influence [Cohen, January 2009]. Latvia, another former Soviet country, has also experienced problems relying on Russian transport agreements as oil shipments through the LatRosTrans pipeline were briefly stopped in 2003. The decision to stop oil shipment through the LatRosTrans pipeline was a method of demonstrating Russian frustration with Latvia for building closer relations with Europe and threatening Russian security by joining NATO [Gidadhubli, 2003]. As Europe ushers in 2010 it is bracing yet again for the prospect of an energy supply crisis, Russia is threatening to stop oil shipments to Europe which run through Belarus [Kramer, 2010]. Until January 1, 2010 Belarus had been the beneficiary of an oil price subsidy which earned the country billions of dollars in revenue through selling Russian oil at a profit to Europe. The subsidy was meant to keep Belarus firmly within Russian control by bolstering the regime of Aleksandr Lukashenko. Russia, however, has decided not to renew the subsidy in response to apparent Belarusian attempts at rapprochement with Europe. In 2009 Belarus agreed to join the EU's Eastern Partnership, a program meant to build closer ties between the EU and post-Soviet countries Armenia, Azerbaijan, Georgia, Moldova, and Ukraine [Pop, 2009]. Sergei Lavrov, the Russian Foreign Minister, has expressed Russia's displeasure over the Eastern Partnership program calling it a means of extending the EU sphere of influence further east [Pop, 2009]. Belarus further irritated Russia by failing to support Russian recognition of Abkhazia and South Ossetia, territories within Georgian borders, as independent states. It can be assumed that, much like the crisis with Ukraine, a new supply contract will be signed between Russia and Belarus, albeit at a much higher rate.

It is too early to know whether or not oil shipments to Europe will be affected due to the Belarus-Russia dispute, however the it once again calls into question the ability of nations to rely on energy supplies shipped through Russia. The willingness of Russia to use energy supplies for political manoeuvrings has led both Europe and China to seek ways of lessening their dependence on Russian pipelines. The first step in

Europe's effort to bypass Russia was the Baku-Tbilisi-Ceyhan (BTC) oil pipeline. As is implied by the name, the pipeline starts in the Caspian Sea port of Sangachal near Baku, Azerbaijan and crosses through Georgia on the way to the Turkish port of Ceyhan (see Annex 1). Measuring 1,737 km in length [BBC News Sept. 17, 2002], the BTC pipeline was the first link between the Caspian and Mediterranean Seas and has a capacity of 1 Mb/d [Cohen, 2005]. The pipeline was not designed to exclusively transport Azerbaijani oil as it also gives Kazakhstan a non-Russian alternative for shipping oil to Europe. The Nabucco pipeline is another step in plans to mitigate Europe's dependence on Russia energy supplies. The pipeline is a direct challenge to Russia which has been trying to hold onto Gazprom's monopoly of supplying natural gas from Central Asia to Europe [Kramer, 2009]. Construction on Nabucco will begin in 2011 and is projected to take four years to complete whereupon is will supply Europe with 31 billion cubic meters of natural gas per year [Nabucco Gas Pipeline Project]. The scope of this project shows how desperate Europe is to diversify energy sources. The pipeline will travel 3,300 km through Turkey, Bulgaria, Romania and Hungary before ending in Austria, with an estimated cost of €7.9 billion (Annex 1[Nabucco Gas Pipeline Project]). Although Chinese energy supplies from Russia have not yet been subjected to threats of interruption, China has surely been paying attention to the events in Europe. Chinese energy consumption is projected to increase dramatically over the next 20 years and so Chinese energy companies have been scouring the globe in an effort to secure energy contracts. Despite their urgent need to secure energy supplies China is wary of depending too heavily upon Russia. China has decided to take proactive measures to prevent a Russian monopoly on energy supplies flowing eastwards by building a pipeline to Xinjiang from Turkmenistan through Uzbekistan and Kazakhstan. The 1,800 km pipeline is scheduled to be completed in 2013 and will play a significant role in meeting China's energy needs in the future; the pipeline will carry 40 billion cubic meters of natural gas a year, equivalent to half of China's current consumption [Kramer, 2009]. It is impossible to conclusively state that Chinese and European construction of these pipelines would not have been undertaken had Russia proven more reliable. It is clear, however, that Russian intimidation has definitely created concerns in Europe and China over the security of energy supplies coming from

Russia. These concerns have helped ensure that the large pipeline projects would go ahead. Russia's energy reserves guarantee that they will remain important suppliers to Europe and China but their tactics have prevented them from maximizing the value of those reserves. Better relations with other nations could have resulted in greater cooperation with Russia at building a larger export capacity to Europe and China.

1.5 Liberalism in the American-Canadian Oil Trade

The United States and Canada have formed a deep relationship which extends much further than simply being geographic neighbours. Current relations between the countries are excellent as both enjoy the benefits from having good political communication and deep economic ties. Unlike the realist framework which defines the relations between OPEC oil producers and Western nations, or between Russia and its neighbours, the American-Canadian relationship is defined by liberalism. Greater integration between the two countries has come through trade liberalization which began in 1965 with the signing of the U.S.-Canada Auto Pact and was further accelerated with the agreement of the bilateral Free Trade Agreement (FTA) of 1989. The FTA was later expanded to include Mexico when Canadian Prime Minister Brian Mulroney, American President George H.W. Bush and Mexican President Carlos Salinas agreed to sign the North American Free Trade Agreement (NAFTA) on the 1st of January 1994. NAFTA has formed one of the largest free-trade areas in the world and covers a region with a combined population of over 444 million people and economic output of US$17 trillion [Nafta Now,, see Annex 1]. The FTA and NAFTA have also defined the guidelines of the energy trade and established laws which the member countries have agreed to abide by. Establishing bilateral trade laws in the critical energy sector builds further confidence that Canada can play a vital role in enhancing American oil supply security over the long-term.

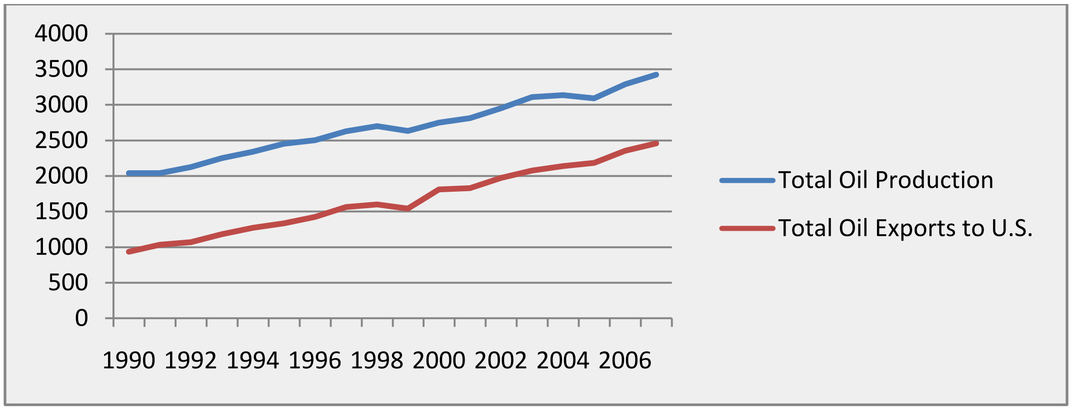
Throughout the 20th century relations between the United States and Canada were relatively peaceful. While wars raged in Europe, Africa, and many other parts of the world, North American relations never deteriorated to the point where armed conflict was considered. Relations between Canada and the United States, however, have also faced their difficulties from nationalistic ambitions. As the center of the oil producing world began to shift to the Middle East in the mid-20th century, American oil producers sought protection to preserve their domestic market. Canada, originally exempted from oil import restrictions by the Eisenhower Administration in 1959 [CERA Growth in the Canadian Oil Sands, 2009], had surcharges levied on its oil exports to the U.S. by President Nixon in 1971 [Finlayson, 1984]. Although these surcharges were meant to control American inflation and were applied equally on every importer, for many Canadians it signalled that the special relationship with the United States was over [Finlayson, 1984]. There was no immediate response from the Canadian government to the surcharge, however it changed Canadian perceptions of cross-border trade and investment, by the end of the decade foreign control of Canadian industries had become a highly debated subject. Many Canadian industries were largely in the hands of foreign firms by the beginning of the 1980s; 45.6% of manufacturing was controlled by foreign firms, heavy machinery 55.4%, and transportation equipment 73.4% [Finlayson, 1984]. The oil and gas industry was no exception; 62.7% was controlled by foreign firms with American firms controlling 47.4% [Finlayson, 1984]. In an attempt to regain control over the energy industry the Liberal government of Prime Minister Pierre Elliot Trudeau created the National Energy Program (NEP) in 1981. The NEP was an attempt by the government to "Canadianize" the domestic oil industry by reducing the level of foreign ownership and increasing the stake of the federal government in energy production. To the United States, the NEP sounded similar to the nationalization trends which removed multinational oil firms from countries like Mexico, Libya and Iran, among others. The goal of the NEP was to have at least 50% Canadian ownership of the energy industry by the end of the 1980s and it resulted in straining the relationship with the United States [Finlayson, 1984]. The situation risked getting out of control with the threat that the two neighbours could become increasingly protectionist. By the end of the decade Canada had reversed its course and agreed to a free trade agreement with the United States.

The FTA and NAFTA epitomize the neoliberal framework which has come to define the Canadian-American relationship since 1990. The overall objective behind the FTA, and then NAFTA, was to improve regional cooperation and expand trade by strengthening the rules and procedures of intra-continental trade. One of the primary ways of meeting this objective was to "eliminate barriers to trade in, and facilitate the cross-border movement of, goods and services between the territories of the Parties" ([NAFTA, Chapter 1 Article 102] see annex 1). The process of tariff elimination between the United States and Canada started under the FTA and most tariffs have been eliminated since January 1, 1998. Under NAFTA, tariff elimination on Mexican goods and services was accelerated and by January 1, 2008 virtually all tariffs between Canada, the United States and Mexico had been eliminated [Foreign Affairs and International Trade Canada, Tariff Elimination]. The results oin the 15 years since NAFTA came into effect have shown encouraging signs that the overall objective is being met. Since NAFTA was agreed to, North American merchandise trade has more than tripled to US$946.1 billion in 2008 and employment levels have risen 23% creating a net gain of 39.7 million jobs. [Nafta Now]. These gains from free trade have resulted in the combined GDP of the NAFTA partners more than doubling, from US$7.6 trillion to US$17 trillion.

The free trade agreements have strengthened Canadian-American relations by de-politicizing trade in most sectors. The result has been a large increase in trade with "Canadian merchandise exports to the United States [having grown] at a compounded annual rate of almost 6.3% between 1993 and 2008" [Foreign Affairs and International Trade Canada, Foundation for Canada's Prosperity] with total merchandise trade more than doubling. The trade in services, though much smaller than merchandise, also more than doubled from CDN$42.2 billion to CDN$91.3 [Foreign Affairs and International Trade Canada, Foundation for Canada's Prosperity]. The most important goods and commodities that are traded include autos, auto parts, computer equipment, aircraft equipment, lumber and energy. Total trade has grown to the point where more than US$1.6 billion in goods crossed the border every day in 2008 making Canadian-American trade the largest bilateral trade relationship in the world [Fergusson, 2009]. Of all the items which are traded, none are as vital to the national economies as oil. As the world's largest consumer of oil the United States is dependent upon imports of oil and oil products to meet their consumption needs. Saudi Arabia, Mexico and Venezuela have all traditionally been large oil suppliers to the United States, but since

2004 Canada has been the largest supplier. Increased investments in the oil sector, particularly in the oil sands region of Alberta, has resulted in Canadian oil production and exports substantially increasing. From 1990 to 2007 total Canadian production of oil has increased from 2.04 Mb/d to 3.42 Mb/d while exports to the U.S. have increased from 0.93 Mb/d to 2.46 Mb/d, see Figure 5. Investments in Canadian oil production will continue to increase over the coming decades which should increase Canadian output to approximately 5 Mb/d (see Section 4.5 for details). Such an increase in Canadian oil production creates the possibility that Canada could supply an even greater percentage of oil than the 19% of total U.S. imports it currently supplies [CERA Growth in the Canadian Oil Sands, 2009]. Increasing oil exports to the United States carries few risks for Canada since oil is such a highly sought after commodity. Global demand for oil is projected to grow by over 20 Mb/d between 2008 and 2030 with the greatest amount of growth coming from China and India [IEA World Energy Outlook, 2009]. In the highly unlikely scenario where the United States would ban Canadian oil imports, Canada could easily sell its oil to Asian markets. Although Canada's pipeline infrastructure is currently setup to service the American market there is already a plan in place to build a pipeline from the oil producing area in Alberta to the Pacific port of Kitimat, British Columbia. Once completed the Enbridge Northern Gateway pipeline will be able to carry 525,000 b/d to the Pacific coast [Northern Gateway Pipelines]. Shipped by tankers, Canadian oil would be able to accommodate a portion Chinese and Indian demand growth which is projected to increase by 8.6 and 3.9 Mb/d respectively by 2030 [IEA World Energy Outlook, 2009]. For the United States, the risk of increasing oil supply dependence on Canada could theoretically exacerbate current American oil supply security problems. As demonstrated with the examples of the Arab oil producers and Russia above, increased dependence on Canada could make the United States more vulnerable to oil supply disruptions originating in Canada. This, however, is highly improbable for a number of reasons. First of all, the two countries are connected through a series of pipelines which make the United States the most natural destination for Canadian oil exports. Although the Enbridge Northern Pipeline could ship oil to Asian markets, it can just as easily ship oil to the lucrative Californian

Figure 5: Canadian Oil Production and Exports to the U.S. (thousand barrels per day)



Source: EIA International Energy Statistics

market which is a far more attractive prospect for Canadian oil producers. Canadian oil producers do not make any money shipping oil so their net returns are highest when selling oil to closer markets [Guly, 2005]. Maximizing revenue not only in the best interest of the oil producers; the federal government receives 43% of the revenue from the oil sands and the government of Alberta receives 36% [Guly, 2005]. It is therefore in the federal and provincial governments' best financial interest to sell greater volumes of oil to the United States. The most important issue, however, remains NAFTA. The United States can feel secure in increasing their reliance on Canadian oil due to chapter 6 of NAFTA which explicitly covers the trade in oil and other sources of energy. Articles 603, 604 and 607 prohibit the imposition of taxes, quotas, or quantitative restrictions in the energy trade. Barring an unexpected national emergency or war, the Canadian government cannot legally reduce oil exports to the United States. This agreement is beneficial for both parties; the United States is assured of access to Canadian oil supplies while Canada is assured of access to the American market. Finally, the United States can rely on Canada as a secure source of oil. The Energy Security Index compiled by Energy Security News and the Washington Post rated Canada as the most secure energy producing country in the world [DeBard, 2009]. According to the study the Canadian oil exporting industry suffers the least potential disruption from "government or internal strife, terrorist attack or a sudden inability to ship by sea" [DeBard, 2009]. As a result of the neoliberal framework provided by NAFTA, in addition to other factors mentioned, the United States can feel secure increasing oil imports from Canada and will see their oil supply security improve.

CHAPTER 2: GLOBAL SUPPLY AND PRODUCTION OF OIL

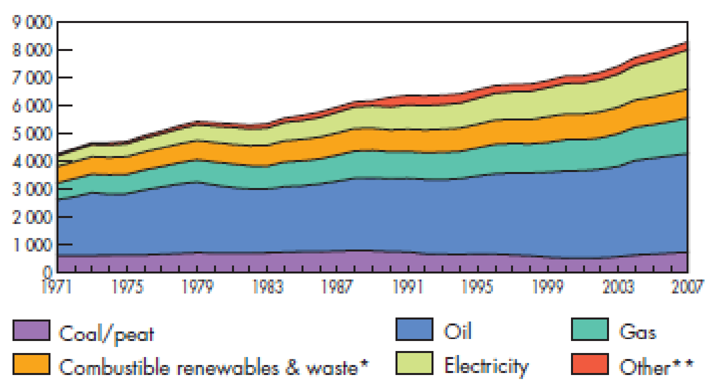
If there is one certainty in the oil industry it is that the Earth's supply of oil will one day run out. The hydrocarbon-rich substance we know as crude oil was formed underground from the remains of plants and animals that were subjected to geological heat and pressure in a process that took millions of years. At the current rate of extraction of 85.4 million barrels per day (Mb/d) [EIA International Energy Statistics], the remaining lifespan of global oil supplies can be measured in decades. Although disagreements abound among politicians, environmentalists and energy industry executives, they all concede that the Earth's endowment of crude oil is a non-renewable resource which must be properly managed. One of the most contentious issues in the energy industry, however, is the ability of remaining global oil reserves to meet future demand. Considerable debate exists about when the world will reach the point of peak oil production with the most pessimistic of forecasts claiming that we are presently at the peak with future oil production sure to decline due to physical limits. The more optimistic reports assert that global oil reserves are more than sufficient to meet the rising demand up to the year 2030 and perhaps beyond. Since crude oil is the single most important source of energy it is therefore of paramount importance for decision makers to know which of these reports is more accurate. Furthermore, in certain sectors such as transportation there is not as yet any substitute for oil in the near-to-medium future thus making reliable oil supplies vital for national economies. This chapter will first describe the status of current global oil consumption and will subsequently elaborate on peak oil theory. Pessimistic projections published by the Energy Watch Group (EWG) and by Frederik Robelius will then be compared to the reports from international organizations such as the International Energy Agency (IEA) and the Cambridge Energy Research Associates (CERA). Although the era of cheap and abundant oil has past, it seems most likely that current oil reserves will be able to meet future demand so long as the necessary investments are made and energy conservation in taken seriously. Although oil will in all likelihood continue to be the most important primary source of energy up to the year 2030, its total share of energy consumption will decrease. Other energy sources, particularly natural gas and renewable energies, will see their importance increase as the world continues to lessen its dependence on energy derived from oil.

2.1 The Shift to the Oil Age

"It is the material energy of the country, the universal aid, the factor in everything we do." This was how the nineteenth century economist W.S. Jevons had described coal [Yergin, 1991]. As the predominant source of energy in the 19^{th} century, coal had fuelled the Industrial Revolution. Without coal the unprecedented industrial growth would not have been possible and this was clear to Jevons: "With coal almost any feat is possible or easy; without it we are thrown back in to the laborious poverty of early times" [Yergin, 1991]. As the industrial economies of 19^{th} century Europe continued to grow, so did their energy requirements. More factories were built and the production of goods was expanded, none of which would have been possible without the use of coal. For the first time in human history energy, almost exclusively derived from fossil fuels, became the life-blood of the economy and thus of individual countries as well. Coal, however, had one very large drawback; pollution. Perhaps more so than any other city, Manchester came to epitomize the problems with coal and the industrial revolution. In the 17^{th} century Manchester, England was a pretty market town that primarily traded in linens and later, cotton. The cotton industry, as well as Manchester itself, was completely transformed as large mills and factories were constructed in the 19^{th} century. This transformation was fuelled solely by coal shipped via the canal from Lancashire, and soon enough Manchester was stained black from the burning of coal in factories and train engines. Despite the environmental drawbacks, coal remained the primary source of energy until the mid-20^{th} century. Of the total energy consumption is Western Europe in 1955, 75% was provided by coal and only 23% by oil [Yergin, 1991]. Oil, however, has the advantage of being easier to handle and is more environmentally sound compared to coal. While these advantages were surely considered, the widespread conversion from coal to oil was mainly a consequence of economics; increased global oil production resulted in oil becoming cheaper than coal. Of all the factors this one was the most critical. Energy intensive industries gained a competitive advantage by switching to oil and by 1972 60% of total energy use in industrialized countries was derived from oil whereas coal's share had dropped to 22%. This was a complete reversal in only 2 decades. Between 1948 and 1972 the increased consumption of oil in the industrialized nations was phenomenal; U.S. consumption tripled to 16.4 million barrels per day (Mb/d), Western European consumption increased 15 fold to 14.1 Mb/d, and in Japan consumption increased from 32,000 barrels per day to 4.4 million, a 13,750% increase [Yergin, 1991].

The growth of energy consumption has continued unabated following the mass conversion from coal to oil use in the beginning to mid 20th century. In 1973 the total (global) final energy consumption was 4,675 million tons of oil equivalent (Mtoe). The following 3 decades saw the demand for energy grow at an average annual compound rate of 1.7% and in 2007 total global energy demand was 77% greater than in 1973 for a total final energy consumption of 8,286 Mtoe [IEA Key World Energy Statistics 2009]. Figure 6 below shows the increase in energy consumption by fuel between 1971 and 2006.

Figure 6: Evolution of world total final consumption by fuel (Mtoe)



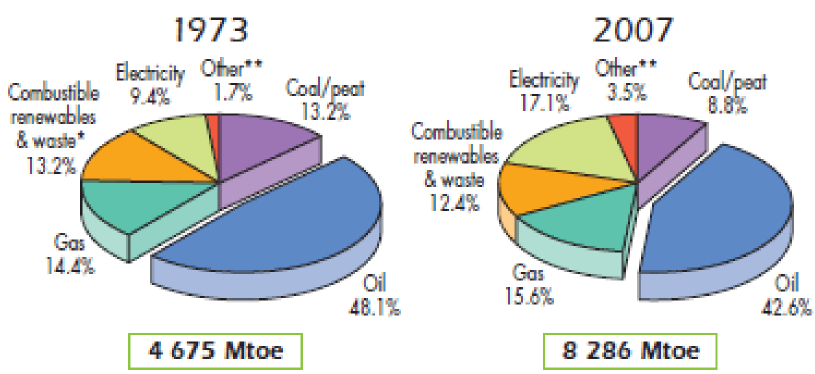
Source: IEA Key World Energy Statistics, 2009

Electricity generation from hydro-dams, nuclear power plants as well as the growth of renewable energy has enabled the world to diversify its sources of energy away from fossil fuels. Oil, however, continues to be the most important source of energy today. Although the share of oil in total global energy consumption has decreased over time from 48.1% in 1973 to 42.6% in 2007, oil still accounts for a much larger share than any other fuel type (see Figure 7). Furthermore, while the total share of oil may have decreased the absolute quantity of oil consumed has greatly increased.

Over the 34 year period the average annual increase in the demand for oil was 1.34% so that in 2007 56% more oil was consumed compared to the 1973 levels; an increase of 1,281.17 Mtoe.

The rise in oil consumption enabled a monumental change in living standards and expectations to occur. Increased vehicle ownership meant that families were no longer restricted to using public railway transportation nor required to live in city centers. New homes built in the suburbs which ringed metropolitan areas were equipped with all sorts of new appliances and gadgets, all of which required electricity. Plastic goods, made from petrochemicals, soon infiltrated homes and work places, and the factories that produced all of these new consumer

Figure 7: Fuel Shares of Final Consumption in 1973 and 2007

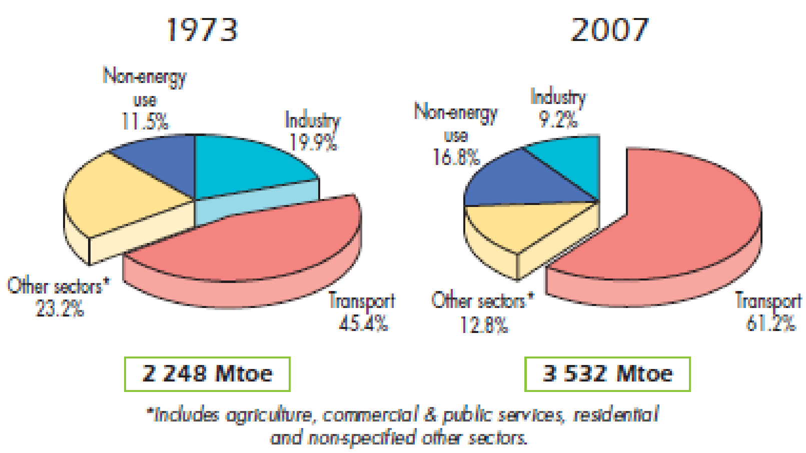


Source: IEA Key World Energy Statistics, 2009

goods were increasingly being powered by oil. Nowhere, however, was the impact of oil greater than in the transportation industry. Between 1949 and 1972 the number of motor vehicles in the United States increased from 45 million to 119 million, while the total outside the United States went from 18.9 million to 161 million [Yergin, 1991]. Today the number stands much higher; according to the *2007-08 World Motor Vehicle Market Report* there were 789.8 million motor vehicles on the road in 2005, or approximately one car for every 8 people. The increase in the number of vehicles resulted in a drastic increase in the share of oil being used in the transport sector. From 1973 to 2007 the share of oil used in transportation increased from 45.4% to 61.2% (see Figure 8 below). This trend is expected to continue as the number of vehicles, particularly in China, continues to increase over the next several decades.

Throughout the 20th century it was fairly uncomplicated for suppliers to meet the growing demand for oil supplies. Conventional oil sources from the Middle East to the United States to Venezuela were more than enough to satisfy the demand. In fact, before the oil crisis of 1973 the biggest problem in the industry was over supply. Discoveries of massive oil quantities were made across the Middle East and northern Africa in the middle part of the century and every nation was eager to profit from their natural endowments. Although critical to the economies of consuming nations, for the producing countries oil provided a valuable source of foreign currency in addition to "power, influence, significance and status" [Yergin, 1991]. As such, the producing nations started to compete with one another for greater market share of their oil, and

Figure 8: Oil Consumption by Sector in 1973 and 2007

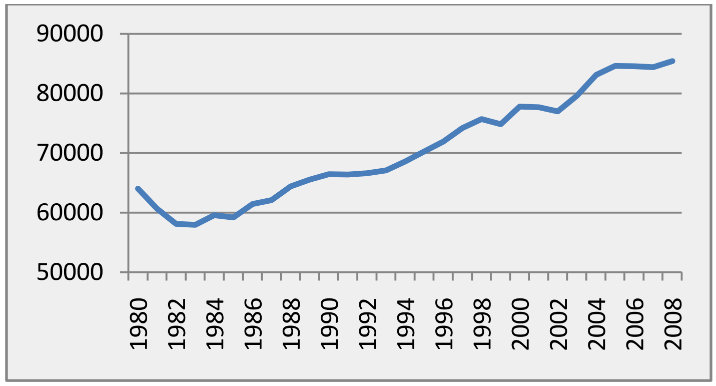


Source: IEA Key World Energy Statistics, 2009

in order to do so they increased production and would often cut the price of oil. The result was an explosion in the world oil supply, from 8.7 Mb/d in 1948 to 42 Mb/d in 1972 [Yergin, 1991]. Even more remarkable was the enormous regional shift in the location of oil fields. Despite the United States increasing production by 4 Mb/d over that time period, the US share of total world oil production plummeted from 64% to 22% [Yergin, 1991]. The reason for this drop was that oil production in the Middle East over the corresponding period had gone from 1.1 Mb/d to 18.2 Mb/d, an increase no one could have foreseen when prospectors first started exploring the region at the beginning of the century.

The rise in oil production throughout the 20th century has been nothing short of remarkable. Despite oil embargoes and wild price fluctuations during the 1970s the overall demand and production of oil did not wane over the long term. Oil production declined over the first half of the 1980s but rebounded before the end of the decade for an overall increase from 64 Mb/d in 1980 to 66.4 Mb/d in 1990. By the year 2000 oil production was at 77.8 Mb/d and further increased to 85.4Mb/d in 2008 (see Figure 9). The overall production trend seen in Figure 9 clearly points in an upward direction, however it would be wrong to simply extrapolate future oil production based on past experiences. Oil demand in the future will depend on a number of factors unrelated to the physical supply of oil. Many countries have already drafted legislation to curb the use of fossil fuels or are in the process of doing so in a bid to reduce carbon dioxide emissions. Oil importing countries are also diversifying energy sources away from oil in order to improve their energy security and diminish the power of the exporting countries. However as conventional oil reserves continue to diminish considerable debate exists about the ability of global oil supplies to meet future demand. Estimates of recoverable global oil reserves vary according to sources greatly influencing projections of future availability. It is widely assumed that almost all of the giant oil fields have already been found with most new discoveries likely to be smaller than 10 Gb. Large sources of unconventional oil have been identified but require new technological advances in extraction and refining before large volumes can be produced. One such source is the Canadian oil sands where new refining processes are required to create a synthetic crude oil from the molasses-like mixture of sand, water and bitumen. Several kilometres offshore from Brazil, oil rigs are pushing technological limits by digging several kilometres below the sea level, through layers of hard rock and salt which are more than one thousand meters thick in some areas, in order to reach the Tupi oil field. These new technologies require huge investments which may not be made in time to avoid an oil supply crisis. The many challenges and potential problems faced by the oil industry questions whether or not the world supplies are sufficient.

Figure 9: World Oil production 1980-2008 (thousand barrels per day)



Source: EIA International Energy Statistics

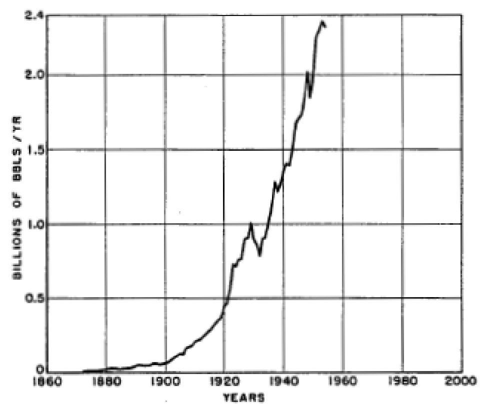
2.2 Peak-Oil Theory and Hubbert's Curve

The incredible spike in oil prices in 2008 brought with it a lot of discussion about whether there remains enough oil to meet global demand. Between 2006 and mid-2007 the price of oil traded between \$55 and \$68 per barrel with a high of \$71.45 per barrel during the second week of August 2006 [EIA Petroleum Navigator]. Starting in mid-July of 2007 the price began climb ever higher until reaching an all-time high of \$136.32 exactly one year later in the third week July 2008 [EIA Petroleum Navigator]. The high prices dominated news headlines and caused panic among the oil importing nations. By the end of 2008 prices had relaxed and by the end of December 2008 a barrel of oil traded at \$35.99, its lowest level since the third week of 2004 [EIA Petroleum Navigator]. Not only did the massive fluctuations in the price of oil have a negative impact on many nations' economies, it also made many people think about the possibility of a scarcity of oil in the near future. One of the earliest attempts at predicting the oil peak[3], however, was done at a time when the average person was blissfully unaware of the potential scarcity of oil. In the mid 1950s M. King Hubbert, a geophysicist for worked for Shell Oil before joining the U.S. Geological Survey, looked at the increase in the production of oil both in the United States and on a global scale and could read the writing on the wall. Between 1880 and 1930 the United States production of oil steeply increased at a yearly rate of 7.9% with a doubling of output every 8.7 years, as shown in Figure 10 [Hubbert, 1956]. The overall increase in global

[3] The "Oil Peak" refers to the point in time when oil production reaches its maximum rate before beginning an irreversible decline

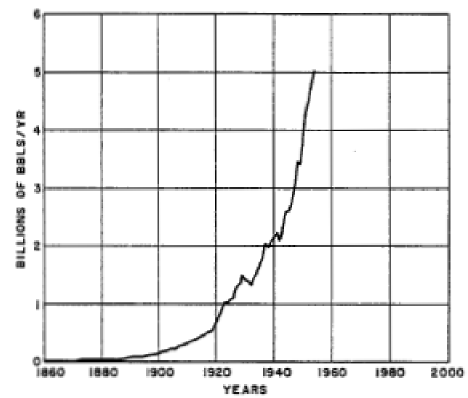
oil production rates closely matched those in the United States with a yearly increase in production of 7% and a doubling of output every 10 years, see (Figure 11 [Hubbert, 1956]). By the end of 1955 the cumulative production of crude oil in the United States was approximately 53 billion barrels. What is interesting to note is that the first half of the 53 billion barrels took 80 years to be produced (1859-1939) while the second half was produced in only 16 years [Hubbert, 1956]. Hubbert realized this upward trend in production levels could not last forever leading him to develop a model of peak oil known today as "Hubbert's curve".

Figure 10: U.S. production of crude oil (1860-1950)



Source: Hubbert, 1956

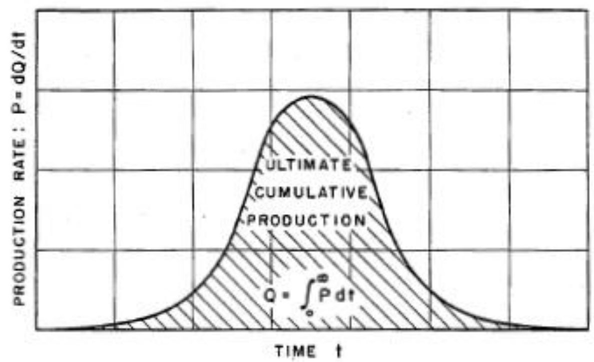
Figure 11: World production of crude oil (1860-1950)



Source: Hubbert, 1956

Hubbert started with the knowledge that the only known production points are at time t=0 and t=∞, the points when the level of production is equal to zero. He then used simple calculus to derive a possible bell-shaped production curve, as seen in Figure 9 (see annex 2 for Hubbert's calculations). The shaded area under the curve is equal to the total amount of the resource that can be extracted from the ground while the curve represents the rate of production. His basic premise was that once oil production began in a new oil field the rate of production would rapidly increase, as had already been observed in various oil fields around the world (Figures 10 and 11). Production can be expected to increase until physical limits prevent further expansion of production with the peak occurring sometime at the point where 50% of the well reserve had already been extracted. After a short peak and plateau, production would decrease at approximately the same rate at which it had previously increased (see Figure 12).

Figure 12: Mathematical Relations involved in the complete cycle of production of any exhaustible resource

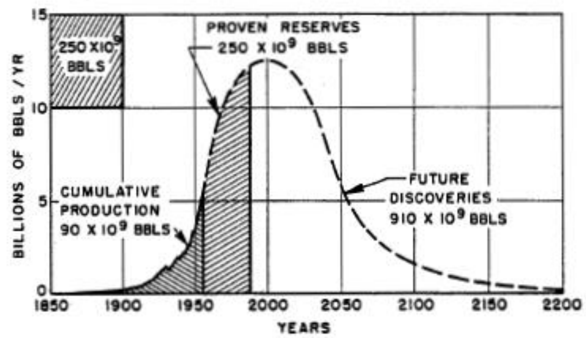


Source: Hubbert, 1956

Hubbert applied his theory using the oil data available at the time to predict when the U.S. and global oil production peaks would occur. Despite objections from his employer, Shell, Hubbert came out with his prediction that US oil production would peak in the early 1970s in a 1956 at a meeting of the American Petroleum Institute in San Antonio [Deffeyes, 2008]. According to Kenneth Deffeyes, Professor Emeritus of Geology at Princeton University and a former colleague of Hubbert's, the prediction was rejected by almost everyone both inside and outside the oil industry [Deffeyes, 2008]. For the next decade and a half Hubbert's critics seemed justified in their critique as American oil production continued to increase from approximately 7 Mb/d in 1955 to over 11 Mb/d in 1970 [EWG, 2007]. With the advantage of hindsight it is now known that Hubbert's prediction was very accurate and U.S. oil production peaked in 1970. Approximately 3.5 billion barrels of oil were produced in the US in 1970 before production fell to 3.45 billion barrels the following year with the trend continuing thereafter [EIA Petroleum Navigator].

Given that Hubbert's prediction of the U.S. production peak was remarkably accurate, consideration should be given to his global production predictions. Without the advantage of the technology and accumulated knowledge available to today's geologists, Hubbert was forced to make certain assumptions on global oil reserves and on the maximum future production rate. He estimated total global reserves of 1,250 billion barrels (Gb) and a maximum rate of yearly production of approximately 12.5 Gb. Using these assumptions he calculated that global peak production would occur in the year 2000, see Figure 13 [Hubbert, 1956].

Figure 13: Hubbert's global oil peak production prediction

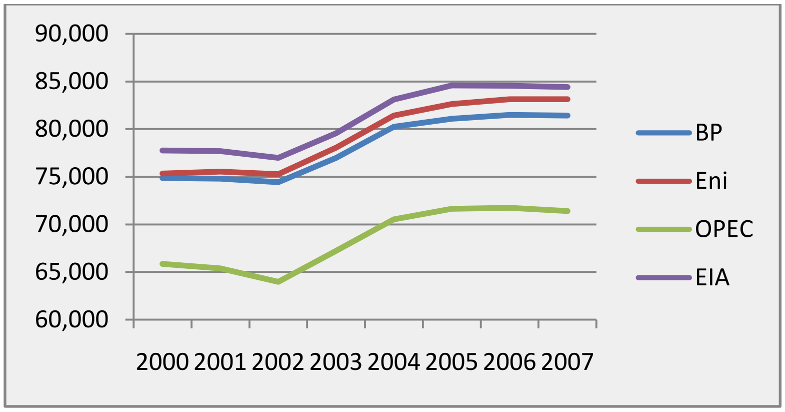


Source: Hubbert, 1956

Current data shows that Hubbert's calculation of a peak occurring in the year 2000 was inaccurate. Production statistics for the years 2000 to 2007 show that the production of oil has not yet leveled off, see Figure 14 below. Statistics provided by four different sources show that production of oil has continued to increase since the year 2000, albeit at a much slower rate than during the 1950s when Hubert was making his predictions. Although it appears as though Hubbert's prediction of a global peak in the year 2000 has been off the mark, it must be kept in mind that his prediction was made 40 years earlier. The assumptions used in his theory were founded on educated assumptions that were based on the history of oil production up to 1956. The largest source of error in Hubbert's calculation was in his estimation of total global oil reserves. In his 1956 study he estimated that there were 1,250 Gb of global reserves. Current estimates from BP show global reserves at the end of 2007 to be 1,238.892 Gb, while *World Oil's* 2007 year-end estimate was 1,184.208 Gb [EIA World Proved Reserves of Oil and Natural Gas]. According to the Oil & Gas Journal global reserves are even greater; 1,342.207 Gb as of January 1, 2009 [EIA World Proved Reserves of Oil and Natural Gas]. Oil reserves are therefore estimated to be greater in 2009 than they were in 1956 despite the fact that approximately 900 billion barrels of oil were extracted over those 50 years. The reason is that oil reserve estimates are frequently updated as new oil fields are discovered and as more knowledge about remaining oil fields is accumulated.

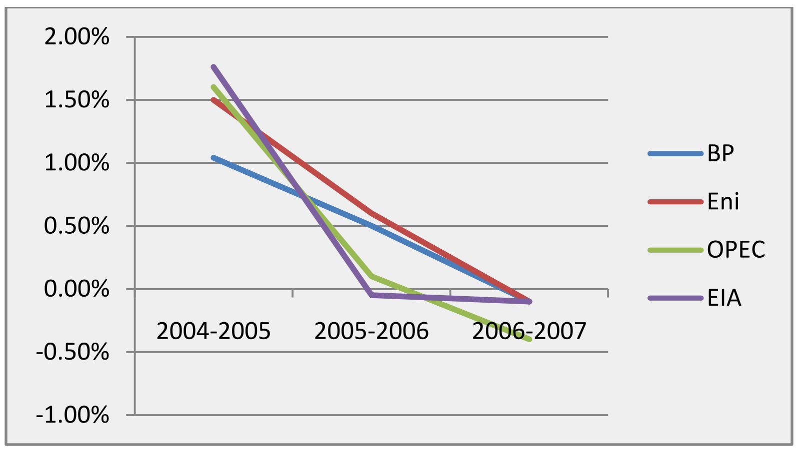
Advances in technology have enabled oil companies to gain a better understanding of the shape and size of oil fields so that the volume of oil is better estimated. Technological advances have also helped oil companies extract oil more efficiently than ever before so that greater volumes of oil can be pumped out of every well. Enhanced Oil Recovery (EOR) techniques have been developed whereby water or gas is pumped into an oil field further enhancing oil recovery. Oil production is no longer constrained to on-shore drilling either, with deep water rigs making oil fields off the coast of Africa and Norway accessible for extraction. Hubbert's lack of precision can well be understood given that he was using the best data available to him in 1956. It should however be noted that his model and the assumption of the bell-shaped curve is remarkably accurate at describing the pattern of oil extraction (see Annex 2 for examples). In spite of Hubbert's miss estimation, it is possible that a global production peak may still occur in the near future. If we exclude the first set of years and focus on the years 2005-2009 we see that there is actually a contraction in global production levels (see Figure 15). It cannot be conclusively argued that this small drop in production rates shows any clear pattern that implies a peak of global production. Unfortunately it is impossible to know with any certainty whether this recent fall in production is a product of exogenous factors such as high oil prices, supply disruptions, wars or recession, or is in fact the first sign that we have already reached peak production. If the global economy begins to recover from the financial crisis in 2010, it can be expected that oil demand will recover as well. Only when production is incapable of meeting demand can it be stated as fact that the world has passed the oil peak. Despite the erroneous assumptions included in M. King Hubbert's model for global oil production he is not alone in predicting an oil peak occurring at the beginning of the 21st century. Other studies, most notably the supply outlook provided by the Energy Watch Group (EWG) and the doctoral thesis of Frederik Robelius, have respectively estimated that the global peak in oil production will occur sometime between 2006 and 2008. [EWG, 2007 and Robelius, 2007).

Figure 14: Global oil production rates 2000-2007 (thousand barrels per day)



Sources: BP Statistical Review 2009, Eni World Oil and Gas Review 2008, OPEC annual statistical bulletin 2008, EIA International Petroleum Consumption

Figure 15: Growth rates of oil production between 2004 and 2007



Sources: BP Statistical Review 2009, Eni World Oil and Gas Review 2008, OPEC annual statistical bulletin 2008, EIA International Petroleum Consumption

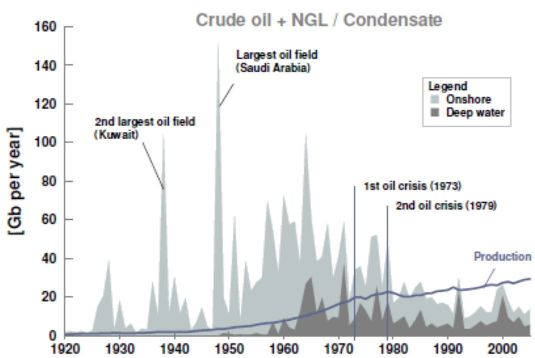
2.3 From Hubbert to the Energy Watch Group

In his 1956 paper *Nuclear Energy and the Fossil Fuels*, M. King Hubbert drew the analogy that finding oil fields followed the same pattern of discovery as that of land in the 16th century. In uncharted waters explorers were most likely to first discover the largest pieces of land, continents. After the continents were drawn maps had to be continually revised as other smaller discoveries were made. Over time, as geographical knowledge progressed, the size of the discoveries were continually smaller until all that was left to find were the smallest, least habitable islands. Figure 16 shows the discoveries of New Field Wildcats[4] since 1920 and demonstrates that Hubbert's analogy was not misplaced. Burgan (in Kuwait) and Ghawar (in Saudi Arabia) are two of the largest oil fields in the world and were discovered in 1938 and 1948 respectively [EWG, 2007]. Many oil fields have been discovered in the years since those massive finds, but the average size of new discoveries have been getting progressively smaller. Between 1960 and 1970 the average size of a new discovery per New Field Wildcat was 527 million barrels (Mb) whereas between 2000-2005 the average size declined to 20Mb [EWG, 2007]. Figure 17 shows the declining average size of field discoveries since 1940. These numbers may be somewhat troubling for the oil industry but do not in themselves prove that the world will face an immediate oil shortage. When Ghawar was discovered in 1948 oil exploration was still at an early age and was taking place almost exclusively in the United States. Geologists at the time did not have a great amount of knowledge as to where oil fields could exist and therefore it is most likely that exploration during that time would yield either a massive find or nothing at all. The result of finding fewer, but larger, oil fields is that the average size of these fields would end up being large. However in the decades since the discovery of the giant oil fields in the Middle East exploration has intensified and spread out around the world. New technologies in exploration have enabled the discovery of a greater number of oil fields regardless of size. The experience of the Occidental Oil Company in Libya is a case in point. In search of new reserves Occidental decided to place their bets on the newly accessible oil fields in Libya where significant oil deposits were believed to exist. Occidental had managed to acquire fields Number 102 and Number 103 but faced early adversity as the first few wells turned up dry. Undaunted Occidental soldiered on and was rewarded with a significant discovery in the most unlikely of spots, right under a former Mobil Oil base camp [Yergin, 1991]. The same blocks of land had previously been awarded to Mobil Oil, who after not finding any oil decided to relinquish their rights to the land. Using newly developed seismic mapping Occidental was able to find oil where others had failed. Exploration technology has progressed since Occidental used seismic mapping in 1966 and this has enabled the

[4] New Field Wildcat: A new oil field located on a structure which has not produced oil before and which is far from other producing fields [Louisiana Energy Topic, 2002]

discovery of greater numbers of smaller fields. As the number of smaller finds increases it will inevitably cause the average size of oil fields to decrease and disguise the discovery of larger fields. The discovery of the Kashagan oil and gas fields in the year 2000 in Kazakhstan illustrates this point. The average size of offshore discoveries was 10 Gb (see Figure 17) yet the Kashagan field is estimated to contain anywhere between 13 Gb [Cardais, 2008] and 38 Gb [Yenikeyeff, 2008]. While it is interesting to notice the decreasing size of average fields, it is of significantly greater importance to know the total size of recoverable oil reserves. It is from these total reserve numbers that future production estimates can be properly estimated.

Figure 16: Discovery of New Field Wildcats



Source: EWG Crude Oil Supply Outlook, 200

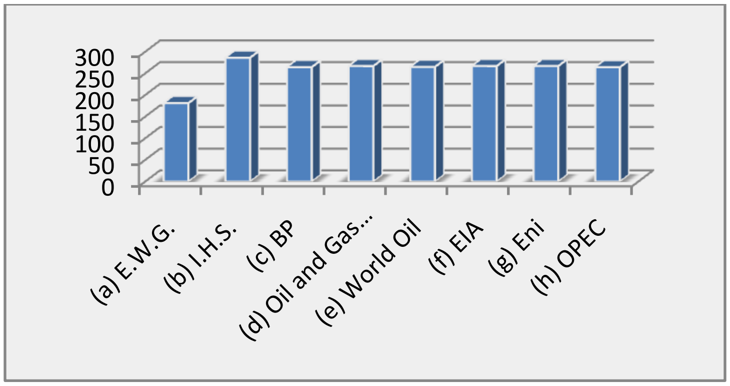
Figure 17: Average size of New Field Wildcats

Period	Average oil discoveries [Gb/yr] onshore	Average oil discoveries [Gb/yr] offshore
2004/2005	7	5
2002/2003	5	8
2000/2001	7	10
1990-1999	8	7.1
1980-1989	14	6.9
1970-1979	24	14.8
1960-1969	42	13.4
1950-1959	31	1.2
1940-1949	26	0.3

Source: EWG Crude Oil Supply Outlook, 2007

As the production of petroleum continues to increase so too does the strain on the worlds' remaining oil fields. Ultimately any level of consumption of a finite natural resource such as petroleum is bound to be unsustainable. Although the level of past and current consumption is a known variable, estimates of when global oil production will peak is still uncertain due to the different estimates of world oil reserves. Although the Earth has been endowed with a fixed amount of oil the estimates of the quantity that geologists are confident can be extracted vary quite substantially. Figure 18 shows seven different estimates of global oil reserves. Six out of the seven estimates show reserve numbers greater than 1,150 Gb. The lone exception is the estimate from the Energy Watch Group (EWG) which believes the world reserves total only 854 Gb. The estimate of 854 Gb by EWG is 27% smaller than the next lowest estimate and 39% smaller than the largest estimate, a significant difference. Due to this very low estimate it is no surprise that EWG also has the most pessimistic projections of future oil supply. It must be questioned, however, at how they arrived at their number. The report by the EWG claims to use

Figure 18: Estimates of World Oil Reserves (Gb)



Sources: (a,b) EWG, 2007 EWG, 2007 (c) BP Statistical Review of World Energy 2009 (d,e,f) EIA World Proved Reserves of Oil and Natural Gas (g) Eni World Oil and Gas review 2008 (h) OPEC annual statistical bulletin 2008

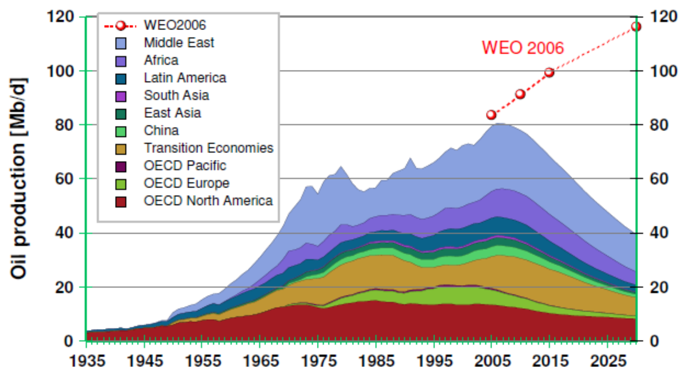
reserve numbers from the IHS[5] database, but they also claim to use their own assessments for the Middle East, USA, Canada, Mexico, Brazil and Russia. These countries are also the largest current oil producing areas in addition to being the areas with the greatest potential to further increase output in the future. Without exception the reserve estimates by EWG have been revised downwards and in no region was the revision as pronounced as in the Middle East. While most estimates of Middle Eastern oil supplies rely on official Figures released by the producing nations, the EWG believes these Figures have been artificially inflated which leads them to estimate that only 362 Gb remain in the Middle East reservoirs as opposed to the industry database (IHS) Figures of 677 Gb. [EWG, 2007] This assumption has some merit due to the structure of production agreements between OPEC member countries. Each member country is only allowed to produce a specific amount of oil in relation to the size of their oil reserves. As the reserve numbers of one country increase, it negatively affects the production level of the other countries. There is therefore ample motivation for all member countries to increase reserve estimates once others have done so too. If, for

[5] IHS is a publicly traded company that provides business information services in 4 principle areas; Energy, Product Lifecycle, Security and Environment. Among their companies is the Cambridge Energy Research Associates (CERA).

example, Saudi Arabia announces their reserves have increased by 10% in a given year then there is the temptation for Iran, Venezuela or any of the other members to announce a similar growth in reserves to prevent Saudi production from increasing at the expense of the other members. Further complicating matters is the fact that there is little transparency in the oil industries of OPEC countries. Oil data is seen as an issue of national security in many Middle Eastern countries and as such foreign monitors are not given access to the oil fields. However the EWG fails to adequately explain how they arrived at their estimates while also making unsubstantiated claims. They fail to provide any source to back-up their claim that; "it is a fact that more water is pumped into the [Ghawar] field than oil is extracted". [EWG, 2007] Furthermore, when executives of the Saudi national oil company Aramco stated that they would be able to maintain a production of 10 Mb/d until the year 2042, EWG noted that this would only be possible should Saudi proved reserves be 260 Gb, "which they definitely are not". However 260 Gb is exactly what sources including BP, the Oil and Gas Journal, I.H.S, World Oil and the EIA all estimate Saudi reserves to be [EIA, World Proved Reserves of Oil]. Finally, as oil exploration continues and new fields in the Gulf of Mexico, the Arctic, offshore from Brazil and elsewhere are more accurately understood it is most likely that global oil reserve numbers will continue to be revised.

Using their numbers the EWG believes peak oil production "occurred in 2006 with a peak production of 81 Mb/d" and "oil production will decline by about 50% until 2030", see Figure 19. [EWG, 2007] However the projections made by EWG must be seriously questioned. The fact that their revised reserve numbers differ so drastically from all other estimate is reason enough to question their validity. EWG claims to be an independent association of researchers and economic experts but there are reasons to question whether or not the reports they publish are biased against the oil industry. EWG was founded by Hans-Josef Fell, a member of Germany's Bundestag (Parliament) for the Bündnis 90/Die Grünen party (Alliance'90/The Greens) As a member of Parliament Mr. Fell has worked hard to promote the adoption of renewable energy sources and to increase the percentage of energy that comes from renewable sources in Germany among other environmental causes. Renewable energy would be an ideal solution for our future energy needs and will hopefully one day meet all of our energy needs. However it seems as though the report published by EWG provides Mr. Fell with the type of "scientific" support he needs to promote his agenda. As such it cannot be held as very credible and other sources must be used to gain a true understanding of future oil production potential.

Figure 19: EWG projection of energy supply to 2030



Source: EWG, 2007

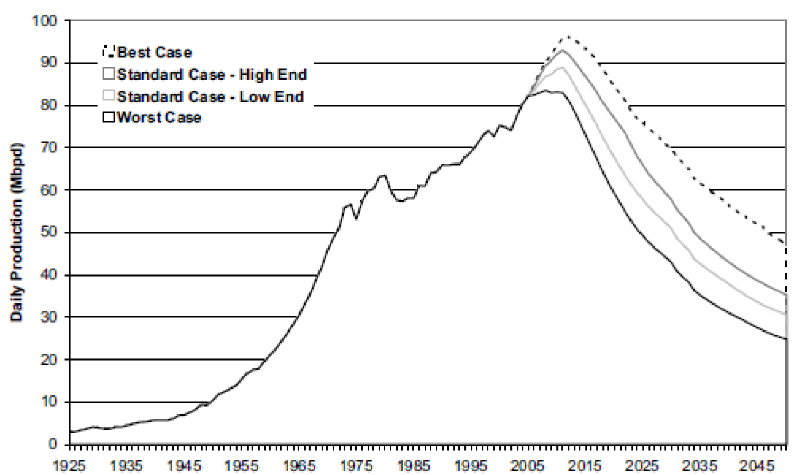
2.4 Robelius' Estimate of Future Oil Production

In his doctoral thesis entitled *Giant Oil Fields: The Highway to Oil,* Frederik Robelius calculated his own projections of future oil production. To arrive at his conclusions Robelius chose to analyze all giant oil fields currently in production in addition to expansions of old fields and new field developments. For his study he determined that a giant oil field is one that will ultimately produce at least 0.5 Gb of oil over the lifespan of the reserve. The total number of oil fields in the world has been estimated to total 47,500, of which only 507 are giant oil fields [Robelius, 2007]. 430 of these fields are currently in production while the remaining fields are in various stages of planning. The overall importance of these giant oil fields is quite remarkable. Of the 2,250 Gb of ultimately recoverable resources estimated by Robelius, approximately 65% is located in the giant oil fields. Thus, while giant oil fields make-up only a small percentage of total oil fields they contain most of the recoverable oil (see annex 2 for a list of the 20 largest oil fields in the world). The giant oil fields are also responsible for most of the world's oil production; in 2005 61% of the world's oil was produced in the 312 giant oil fields and 21 smaller fields which produced at least

100,000 b/d [Robelius, 2007]. This would suggest that the most important factor in determining peak oil is thus the future production of the giant oil fields.

As opposed to the single projection made by EWG, Robelius presented 4 cases; a worst case, standard case (low end), standard case (high end), and best case. His results, shown in Figure 20 below, show a peak occurring as soon as 2008 in the worst case scenario to 2018 in the demand-adjusted best case scenario. The consequence for production by the year 2030 is quite significant; in the worst case scenario production drops to approximately 50 Mb/d while in the best case scenario is approaches 70 Mb/d. In 2008 global oil production reached 85.5 Mb/d [EIA International Energy Statistics], meaning that Robelius is projecting 2030 oil production to be anywhere from 15.5-35.5 Mb/d lower than it is today. This would cause a great struggle between nations for remaining oil supplies and would be extremely damaging the United State's oil security. With China and India both poised to continue consuming greater quantities of oil the United States would need to ensure that their current oil suppliers, particularly Canada, increase production and guarantee oil supplies.

Figure 20: Potential Oil Peaks Calculated by Robelius



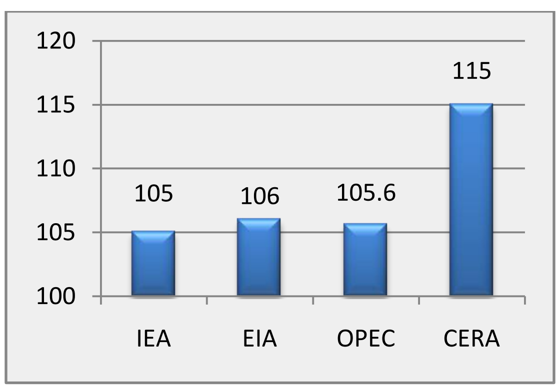
Source: Robelius, 2007

2.5 Projected Oil Demand Growth to 2030

Reports such as the ones from the EWG and Robelius demonstrate that there are serious concerns about the physical supply of oil being able to meet rising demand over the next 20 years. The uncertainties regarding oil reserve estimates coupled with the profitability of the oil industry can create an atmosphere of complaisance where short-term gains are more important than long-term viability. Oil industry insiders have been caught off-guard before; Hubbert's prediction of a peak in American oil production in 1970 was largely denounced before being proven true. Despite being caught off-guard by the limitations of domestic oil production the American economy was not harmed due to the ability to import oil. However the failure to foresee a global peak in oil production would have enormous economic consequences on all oil importing nations. There does not as yet exist an adequate substitute for oil, particularly for transportation, and as such the prospect of an oil supply shortage should be taken seriously. That being said, oil supply up to the year 2030 will be able to meet demand should the necessary investments in pipelines, refineries, and production facilities be made. According to forecasts by influential organizations in the petroleum and energy sector such as the International Energy Agency (IEA), Cambridge Energy Research Associates (CERA), the Organization of Petroleum Exporting Countries (OPEC) and the Energy Information Administration (EIA) there will not be an oil peak between now and 2030. Each of the organizations forecast a rise in the demand for oil with production being able to meet demand up to the year 2030. As opposed to historical trends, future demand growth will not be spurred on by OECD countries but will come primarily from China and India. As demand continues to increase, however, the oil security of petroleum importing nations will be further compromised as the number of oil exporting nations shrinks and supply routes continue to be the targets of terrorist attacks.

The supply of oil faces many potential constraints including "economics, costs, service sector capability, geopolitics, the timing and nature of government decision making, and, centrally of course, investment" [Jackson, 2009]. Global reserve estimates have almost doubled since the 1980s and are not believed to be a constraint on the availability of supply. While most of this increase has come from revisions of oil reserves in OPEC countries, the volume of new discoveries has been greater since the year 2000 than during the 1990s [IEA World Energy Outlook, 2008]. Though estimates vary, the earth is thought to have approximately 1,281.4 Gb[6] of reserves left, a sufficient amount of reserves that will be able to sustain demand if above-ground factors are favourable [IEA World Energy Outlook, 2007, Jackson, 2009, OPEC World Oil Outlook, 2009]. By 2030 it can be expected that the demand for oil will be more than 20 Mb/d greater than in 2008 assuming a growth rate of 1% or less. Although oil production declined from 2005 to 2007, production is forecasted to grow at 1% per year average until 2030 with total production between most likely in the range of 105-106.6 Mb/d, see Figure 21 below for various estimates. The forecast calculated by CERA is substantially greater than other projections and more in line with previous reports. The 115 Mb/d CERA expects to be produced by 2030 is similar to the 116 Mb/d projected by the IEA in their 2007 World Energy Outlook. In the reports released since 2007 the IEA has felt the need to revise this projection downwards, first to 106 Mb/d [IEA World Energy Outlook, 2008] and then 105 Mb/d [IEA World Energy Outlook, 2009]. The downward revision is due to "the impact of higher prices and slightly slower GDP growth, as well as new government policies." [IEA World Energy Outlook, 2008] New legislation in OECD countries, such as the Energy Independence and Security Act (EISA) which was passed in the United States in 2007, will have a great impact on the consumption of oil over the forecasted years. In fact, oil demand from OECD countries is actually projected

Figure 21: 2030 Oil Demand Projections (Mb/d):



Sources: IEA World Energy Outlook 2009, EIA International Energy Outlook 2009, OPEC World Oil Outlook 2009, Jackson, 2009

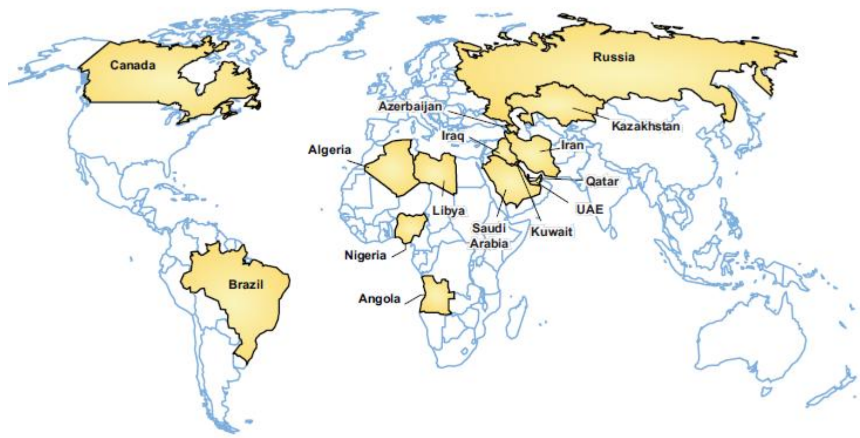
[6] Average reserve estimates from the following publications: BP Statistical Review of World Energy 2009 , EIA World Proved Reserves of Oil and Natural Gas, Eni World Oil and Gas review 2008, OPEC annual statistical bulletin 2008

to drop by 2030 with all of the demand growth coming from non-OECD countries [IEA World Energy Outlook, 2009, OPEC World Oil Outlook, 2009]. The vast majority, approximately 80% [IEA World Energy Outlook, 2008], of non-OECD demand growth will come from Asia and the Middle East, as China and India will increase their consumption by approximately 8 Mb/d and 2 Mb/d over the next 20 years [EIA International Energy Outlook 2009]. Meanwhile consumption in Japan and OECD Europe is projected to decrease by an average of 0.4% and 0.2% [EIA International Energy Outlook, 2009], while oil consumption in the United States will be the same in 2030 as in 2007 [EIA Annual Energy Outlook, 2009].

With demand increasing by over 20 Mb/d between 2008 and 2030 it is important to know where the supplies will come from. OPEC countries account for 70% of the world's total oil reserves [EIA Assumptions to the Annual Energy Outlook 2009] and will therefore continue to play a crucial role in meeting demand. Although the IEA believes "most of the increase in world output would need to come from OPEC countries" [IEA World Energy Outlook, 2009] it is most likely that OPEC will only increase production so as to maintain their current market share. The EIA assumes OPEC production to total 43.8 Mb/d in 2030 [EIA International Energy Outlook, 2009], a level that would allow OPEC to maintain its 40% share in global production. The strongest indication that this is likely comes from OPEC itself which forecasts 2030 production of 41.1 Mb/d of crude oil and 49.6 Mb/d of total liquid fuels production[7], levels that would keep OPECs share of production close to the 40% mark [OPEC World Oil Outlook, 2009]. Expanding output from non-OPEC sources will be a difficult task since oil resources will become increasingly concentrated in fewer countries. Of the 15 countries with the greatest potential to increase oil production between now and 2020, 11 are members of OPEC and only 2 (Canada and Brazil) are in the western hemisphere, see Figure 22. Due to the advancements in extraction technology, unconventional oil production will increase and become a significant source of petroleum. The EIA sees unconventional fuel supply increase by 10.4 Mb/d

[7] Total liquid fuel production includes NGLs (natural gas liquids), GTLS (gas-to-liquids) and crude oil.

Figure 22: The 15 Countries with the Greatest Potential to Increase Oil Production to 2020



Source: CERA, Growth in the Canadian Oil Sands, 2009

by 2030 with 9.6 Mb/d coming from non-OPEC sources such as Canada's oil sands [EIA International Energy Oulook,2009]. Although Canada's conventional oil production will decline by 1 Mb/d over the projection period, output from the oil sands will more than make up for the decline so that by 2030 Canada will produce 5.4 Mb/d [EIA International Energy Outlook, 2009]. Total non-OPEC conventional production will increase moderately, from 48 Mb/d in 2006 to 51 Mb/d in 2030 [EIA International Energy Outlook, 2009] with production increasing in the United States, Brazil, Russia, and Kazakhstan.

2.6 Consequences for Oil Security

The expected changes in production patterns will have a negative impact on the oil security of many nations, particularly the United States. Oil production will become increasingly concentrated in a smaller number of nations, most of whom are currently politically and economically unstable. A quick look at Figure 22 above shows that most of the nations able to increase production are either unstable or have contentious relations with the United States. If the United States were to rely on some these nations for substantial oil imports, they would forever be vulnerable to supply disruptions either from embargoes or terrorist attacks. Russia, for example, is one country the United States is weary of doing business with. Despite the end of the so-called "Cold War" American relations with Russia remain fragile. Furthermore, Russia has gone beyond simply issuing threats and has withheld energy supplies in order to advance their agenda, even at the expense of third parties. In early 2009 Russia stopped all natural gas deliveries to the Ukraine, allegedly over pricing and payment issues, just as Europe was hit with colder than normal winter temperatures. Pricing was not the only issue however. During the Orange Revolution in 2004 Ukrainians protested an election believed by many to have been rigged in favour of the pro-Russian candidate Viktor Yanukovych. Following a run-off election it was determined that the pro-Western candidate, Viktor Yushchenko, won the Presidential elections. In the years following the Orange Revolution Russia has accused Ukraine of supplying Georgia with arms, particularly during the Russian-Georgian war over South Ossetia [Sanders, 2009]. Cutting off the supply of natural gas to Ukraine was not only a way to renegotiate price and payment terms, it was also a strong signal to Ukraine not to interfere in Russian foreign affairs. Caught in the middle were European countries which rely on Russia for approximately a quarter of their natural gas supplies, 80% of which comes through the Ukraine [Sanders, 2009]. In cutting off the gas supply Russia was also sending Europe a message not to engage itself in Russian geopolitical issues. With Russian leaders having demonstrated their willingness to use hydrocarbon supplies as an instrument of power in geopolitical affairs, nations such as the United States would be wise to bypass Russia and seek oil supplies elsewhere. The other options, however, are not necessarily any better. Kazakhstan has an autocratic government and is one of the most corrupt nations in the world[8], Iran is currently under U.S. and international economic sanctions due in part to its nuclear enrichment program, while Libya under the control of Muammar Gaddafi has been a highly unpredictable country. Further south Nigeria and Angola are two countries that have recently emerged from civil wars and continue to suffer from violent attacks. Their oil infrastructures have been targeted by militants and continue to be vulnerable to supply interruptions from the bombing of pipelines. Middle Eastern countries, despite having the largest oil reserves, have also proven to be unreliable oil suppliers as oil embargos and wars have disrupted the global oil supply a number of times (see Figure 4 in Section 1.3). The greatest impact to American oil security comes from the threat of an embargo, as was experienced during the Six-Day

[8] Ranked 162nd out of 180 nations in Transparency International's Corruption Perceptions Index 2009

War in 1967 and the Arab-Israeli War of 1974. Oil embargoes pose the greatest threat to American oil imports since they are applied in response to the particular action of a state or for specific political gains. The embargo in 1974, for example, was done strictly for political motives "i.e. to alter Israeli policy to return territories captured in the 1967 war, to grant the 'legitimate rights' of the Palestinians, and to alter the status of Jerusalem" [Licklider, 1988]. The subject of oil embargoes and oil security has already been examined in Chapter 1.

Potential supply and transportation problems will continue to threaten the United States however American oil security is not doomed. American oil consumption will remain constant over the next couple of decades just as domestic production is set to increase for the first time since 1970 (see Chapter 3). These two factors alone improve oil security as the gap between domestic oil consumption and production shrinks thereby requiring fewer oil imports. Furthermore, the United States can turn to Canada for greater volumes of oil imports. Already the largest supplier of oil to the United States, Canada is the only Western industrialized country among the 15 countries able to expand oil production. Canadian production will increase to over 5 Mb/d by 2030 (see Chapter 4) enabling Canada to export more oil to the United States. Greater dependence on Canadian oil imports will improve American oil security by replacing oil imports from other, less secure, oil production countries. The long history of good relations in addition to the deep economic ties between the two countries ensures that they will work together to achieve the common goal of greater energy and oil security.

CHAPTER 3: AMERICAN OIL SUPPLY SECURITY

Since the end of the Second World War American economic and military strength have grown to the point where the United States has unquestionably become a world superpower. In the four decades following the Second World War the United States was locked in a battle with the former Soviet Union for influence in international affairs, known as the "Cold War". The end of the Cold War was finally achieved not through war or military dominance but rather by the demise of the Soviet model which resulted in economic ruin and the dissolution of Soviet territory. The United States, on the other hand, maintained its dominant position and became the sole world superpower, a position it would not have been able to reach without consuming vast amounts of energy and in particular crude oil.

As the birthplace of the commercial oil industry, the United States was the first country to adopt petroleum as its chief energy source. Throughout the 20th century American economic growth was contingent on growing oil consumption until the economy became entirely reliant on oil supplies. It is difficult to understate the importance of oil consumption in the United States; as former President George W. Bush proclaimed in the 2006 State of the Union address "America is addicted to oil" [Kraemer, 2006]. This "addiction" has resulted in the United States becoming the largest consumer of petroleum by a wide margin. Unfortunately American domestic oil production has been in decline since 1970 and has thus been unable to match the rise in consumption. Consequently, the United States has assumed the position as the world's largest importer of oil and has resulted in the United States being ranked as the least secure energy consuming nation in the Energy Security Index compiled by the Washington Times and Energy Security News. The index ranks oil consuming countries based on their levels of domestic production and imports in addition to the source of their imports. Not only does the U.S. import 12.9 Mb/d (2008 numbers [EIA Petroleum Navigator]) but they rely on countries such as Saudi Arabia, Iraq and Venezuela for their imports. Imports from these countries are less secure due to potential geopolitical issues, terrorist attacks on oil installations, and transportation disruptions. New legislation introduced over the last two years in the United States, such as the Energy Security and Independence Act (ESIA) and a stricter Corporate Average Fuel Economy (CAFE), will improve American's energy security by suspending the growth in oil consumption. This will be achieved by mandating an increase in energy efficiency and greater use of renewable energies and biofuels over the next two decades. To further improve their oil security the United States will need to consider options to boost domestic oil production which has been in decline since 1970. Available options include increasing oil production in the Outer Continental Shelf which has until recently been protected by legislative and federal bans and in the Arctic Natural Wildlife Refuge (ANWR) in Alaska. Finally, expanding Canada's role as the largest oil exporter to the U.S. is also key to improving American oil security. The two countries have had good relations historically and enjoy the largest bilateral trade relationship in the world. In addition to the economic and political stability of Canada, the network of pipelines connecting the two countries provide a much more reliable method of transporting oil compared to shipments via tankers from overseas countries. As oil production increases in Alberta, the main oil producing province in Canada, the United States will be able to depend on Canada's reliable and secure source of oil to make up a greater share of total oil imports.

3.1 American Oil Production 1859-Present

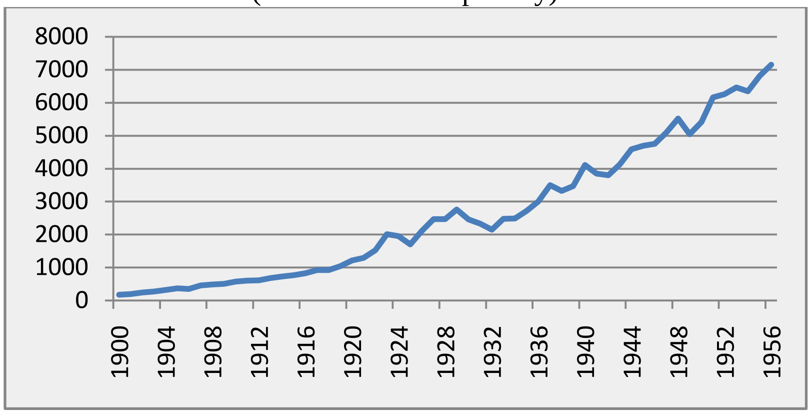
The use of oil has been recorded in the Middle East in the time Before Christ where bitumen[9] was a traded commodity used for many purposes; as building mortar, caulking for ships, road making and medicine [Yergin, 1991]. The use of oil as a medicinal product continued into 19th century America where oil was believed to be a miracle cure for a diverse set of ailments such as headaches, toothaches, upset stomachs, and rheumatism [Yergin, 1991]. The real market potential for oil was not in medicine but as lamp fuel, however oil was not produced in sufficient quantities for this purpose. Oil was observed to naturally seep into springs and salt wells in the north-eastern United

[9] Bitumen(1): "A naturally occurring viscous mixture, mainly of hydrocarbons heavier than pentane, that may contain sulphur compounds and that, in its natural occurring viscous state, is not recoverable at a commercial rate through a well." EIA www.eia.doe.gov/glossary/glossary_b.htm
Bitumen (2): "Petroleum that exists in the semisolid or solid phase in natural deposits." Industry Canada http://www.ic.gc.ca/eic/site/ogt-ipg.nsf/eng/dk00048.html

States and the supply of oil at this time came from "skimming it off the surface of springs and creeks or by wringing out rags or blankets that had been soaked in the oily waters" [Yergin, 1991]. This would forever change in the mid-19th century in the village of Titusville, Pennsylvania. In order to access larger volumes of oil George Bissell, who had recently formed the Pennsylvania Rock Oil Company, had the idea to modify drills used for salt-boring in order to drill for oil which would then be pumped to the surface. Edwin L. "Colonel" Drake was sent to Titusville in December 1957 as the man in charge of making Bissell's vision a reality. After enduring a year and a half of delays and disappointments, Drake finally struck oil on August 27th, 1859 [Yergin, 1991]. The success in drilling for oil and the widespread adoption of kerosene as lamp fuel caused an immediate explosion in production. 500,000 barrels of oil were produced in 1860, a number that would jump to 3 million barrels in 1862 and over 4 million barrels only 9 years later [EIA Petroleum Navigator]. From these humble beginnings emerged the modern oil industry.

Throughout the first half of the 20th century American oil production expanded astonishingly quickly. In 1900 total U.S. production was 174,000 b/d, ten years later 574,000 b/d were produced and by 1920 the rate was greater than a million barrels per day [EIA Petroleum Navigator]. Between 1880 and 1930 American crude oil production increased at an annual rate of 7.9% with total output doubling every 8.7 years [Hubbert, 1956], see Figure 23. The rate of growth was phenomenal; by 1955 a total of 53 billion barrels of oil had been produced but while it took 80 years to produce the first half of this total the second half had been produced in only 16 years [Hubbert, 1956]. As a geologist M. King Hubbert was aware that "although production rates tend initially to increase exponentially, physical limits prevent their continuing to do so" [Hubbert, 1956]. This realization led Hubbert to develop a theoretical model that was meant to approximate the year when oil production would peak in a single oil field, across a country or even on a global scale. For a description of Hubbert's model and the "Hubbert Curve" please refer to Chapter 2, section 2.2.

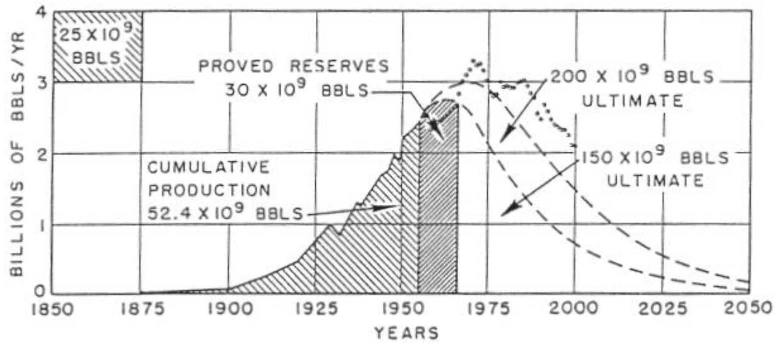
Figure 23: American Field Production of Crude Oil 1900-1956
(thousand barrels per day)



Source: EIA Petroleum Navigator

Hubbert's peak theory hypothesized that oil producing regions would follow a bell-shaped production curve such as the one in Figure 24 below. The curve in the graph represents the rate of production over the life of the oil field. Hubbert assumed that once half of the reserves had been extracted the rate of production would decrease at the same rate that it had previously increased thus creating a symmetrical curve. The area below the entire curve equals the total recoverable reserves of the region, a figure that Hubbert had estimated between 150 Gb and 200 Gb for the entire United States. Using the data available at the time, Hubbert's calculations showed a peak in American production occurring in the early 1970s [Hubbert, 1956]. Although the logic of Hubbert's model was quite simple and straightforward, the conclusions drawn from the calculations were not accepted by the oil industry in general nor by Hubbert's employer at the time, Shell Oil. Due to present his model at the American Petroleum Institute in San Antonio in 1956, Hubbert received repeated calls from the Shell Oil head office requesting him to refrain from submitting his predictions [Deffeyes, 2008]. Since this was not the first time someone had forecasted the demise of American domestic oil production many of Hubbert's contemporaries scoffed at his predictions. At a time when the signs of production decline were not yet evident Hubbert was seen as yet another "false prophet" [Deffeyes, 2008]. The following 14 years only strengthened his critics as production continued to increase from more than 7 Mb/d in 1956 to over 9 Mb/d by late 1969. Many people in the petroleum industry felt there were ample reserves and that the advances in technology which were improving extraction methods

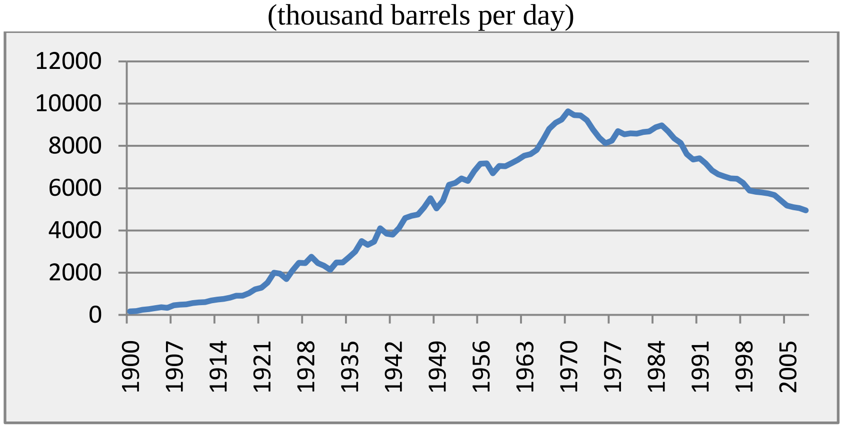
Figure 24: Hubbert's curve for American oil production



source: Deffeyes, 2008

and enabling the discovery of new fields would be able to maintain production growth into the future. In 1971, however, the American oil industry was devastated; Hubbert had been correct. Despite the best efforts of producers, oil production in 1971 could not match the 1970 level as production dropped from 9.637 Mb/d to 9.463 Mb/d [EIA Petroleum Navigator]. American oil production has never again reached the same levels as in 1970 and apart from a temporary boost in production during the late 1970s and early 1980s from the newly producing oil fields in Alaska, American oil production has been on a steady downward trajectory, see Figure 25. In 2008 U.S. field production was 4.95 Mb/d, the lowest level since 1946. Consumption trends, however, have not mirrored the production trends. In spite of dwindling production capabilities American oil consumption has continued to increase throughout the 20th century up until the year 2005, requiring the U.S. to depend more on oil imports thus damaging their oil security.

Figure 25: American Crude Oil Production 1900-2008
(thousand barrels per day)

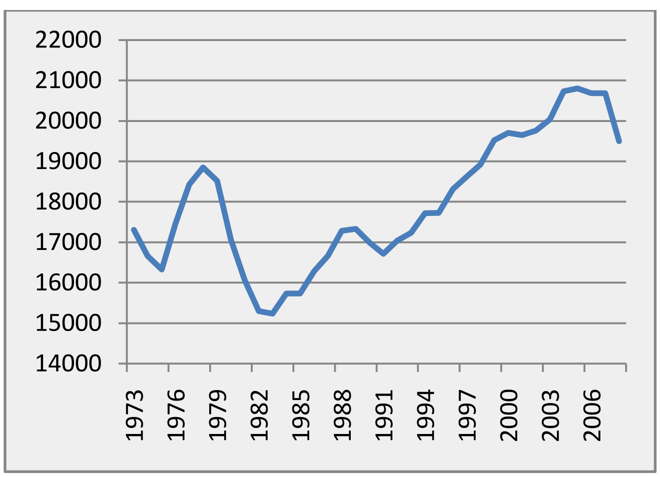


Source: EIA Petroleum Navigator

3.2 The Growth of Petroleum Imports

Despite declining domestic crude oil production, the United States has continued to increase its consumption of crude oil and refined petroleum products. Consumption patterns were volatile during the 1970s however since the early 1980s the consumption trend has pointed in only one direction: upwards. As can be seen in Figure 26, U.S. consumption increased from over 15 Mb/d in 1982 to 17 Mb/d in 1992 and reached the unbelievable rate of 20.68 Mb/d in 2007 [EIA Petroleum Navigator]. This prodigious level of consumption is far greater than any other nation, in fact it is 44% greater than the combined consumption of all European Union Member States (14.38 Mb/d in 2007) [CIA World Factbook: EU]. In 2007 the U.S. consumed 2.6 times more oil than the next highest sovereign nation, China, despite the fact that China's population is more than four times as great, see Table 1. Environmental issues aside, this level of consumption would not be so problematic if the United States was able to match domestic production to demand. However, as mentioned above, American petroleum production has been in perpetual decline and is nowhere near able to meet the demand.

Figure 26: U.S. Consumption of Crude oil and Petroleum Products 1973-2008 (thousand barrels per day)



Source: EIA Petroleum Navigator

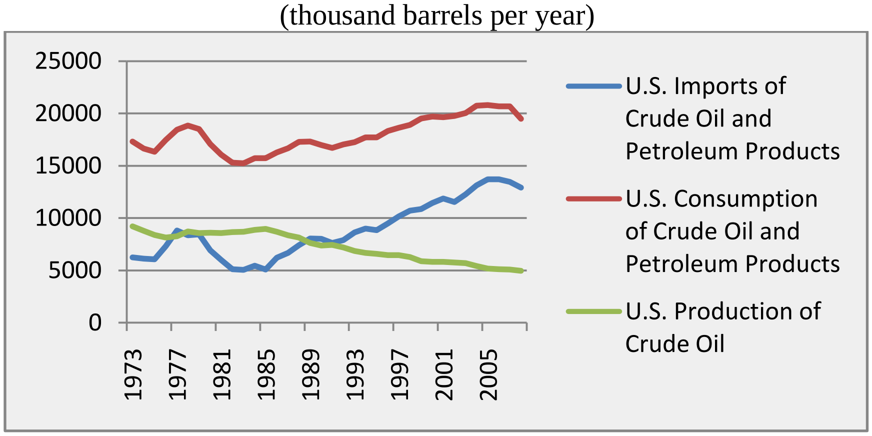
Table 1: Top 10 Oil Consuming Countries in 2007

Country	Consumption (b/d)
1) United States	19,500,000
2) China	7,850,000
3) Japan	4,785,000
4) India	2,940,000
5) Russia	2,900,000
6) Germany	2,569,000
7) Brazil	2,520,000
8) Saudi Arabia	2,380,000
9) Canada	2,260,000
10) South Korea	2,175,000

Source: CIA World Factbook

The trend since 1970 is clearly evident, as oil production declined an increase in oil imports was required to bridge the gap between production and consumption, see Figure 27. Not only has the gross volume of imported oil grown, the percentage of foreign oil to consumption has dramatically increased in only the past 30 years. In 1980 imports made up 40.5% of total consumption, a percentage that has increased every decade up until when imports accounted for 66.2% of consumption, see Figure 28.These percentages clearly demonstrate American vulnerability to oil supply interruptions. It would be absolutely impossible for the United States, even utilizing IEA emergency measures[10], to be able to find alternative sources of oil in the event of a supply interruption due to an oil embargo. At the current levels of consumption and importation the United States has a limited ability to achieve its foreign policy objectives should those objectives run counter to the ambitions of major suppliers such as Saudi Arabia, Venezuela and the rest of the OPEC block.

Figure 27: U.S. oil consumption, production and imports since 1973 (thousand barrels per year)

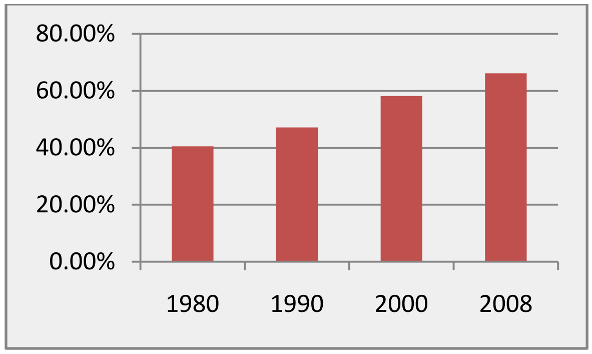


Source: EIA Petroleum Navigator

The United States imported 12.915 Mb/d of oil in 2009 and has relied upon many nations for its growing volumes of imported oil. Saudi Arabia, Venezuela, Mexico and Nigeria are among the largest sources of foreign oil coming to the U.S., however many people may be surprised to learn that Canada is in fact the single largest oil supplier to the United States. Prior to 2004 Saudi Arabia was America's largest supplier of foreign oil with total sales of 629 million barrels of oil in 2003 with Mexico second at 573 million barrels [see Annex 3 for data]. Oil imports from those two countries as

[10] IEA emergency response measures are described in Chapter 1 section 1.3

Figure 28: Percentage of Oil Consumption coming from Oil Imports



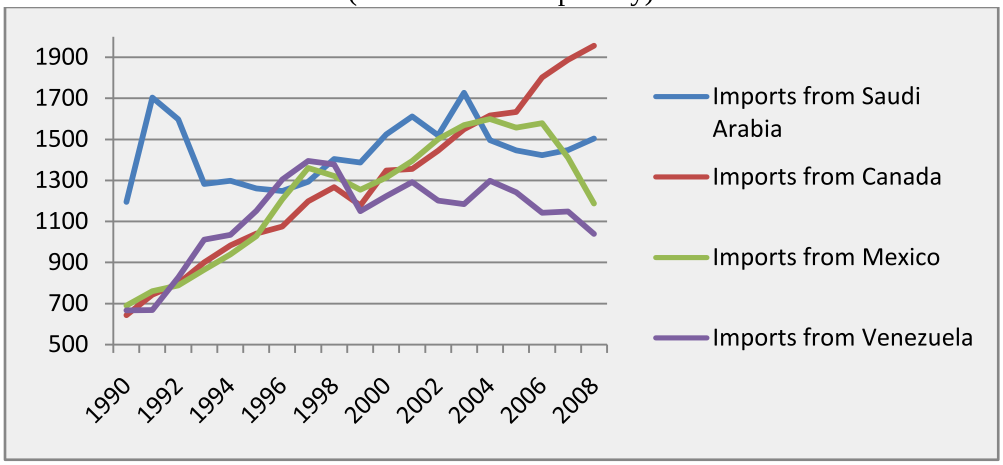
Source: EIA Petroleum Navigator

well Venezuela were highly volatile throughout the 1990s and 2000s. In contrast imports from Canada remained on a steady upward trend, see Figure 29. Canada eventually became the largest foreign supplier of oil to the United States in 2004 and its exports have continued to grow since then. In 2008 Canada sold a total of 715 million barrels, or 1.956 Mb/d, of crude oil to the US, 30% more than Saudi Arabia which is the second largest oil supplier to the U.S. [EIA Petroleum Navigator]. Canadian petroleum exports to the United States in 2008 rise to 2.49 Mb/d when considering total petroleum imports, crude oil in addition to refined petroleum products[11]. Canadian oil exports of 2.49 Mb/d in 2008 were more than 60% greater than the 1.52 Mb/d imported from Saudi Arabia, see Figure 30. Canada is therefore the most important oil exporting country to the United States, accounting for 19% of total petroleum imports to the United States [CERA Growth in the Canadian Oil Sands, 2009].

The growing share of Canadian imports has critical consequences on American oil security. Canada is the only nation among the major American oil suppliers with a modern industrialized economy and a stable democracy. With strong institutions and respect for the rule of law, Canada presents an ideal investment environment for American multinational companies, particularly in the lucrative energy industry. This positive investment environment ensures that, depending on the market price of oil, the proper investments will be made in order to build and maintain oil production and transportation facilities across Canada. Safe investment areas in the energy industry

[11] "Petroleum products include refinery gas, ethane, LPG, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirit, lubricants, bitumen, paraffin waxes, petroleum coke and other petroleum products through distillation" source: IEA, Petroleum Products

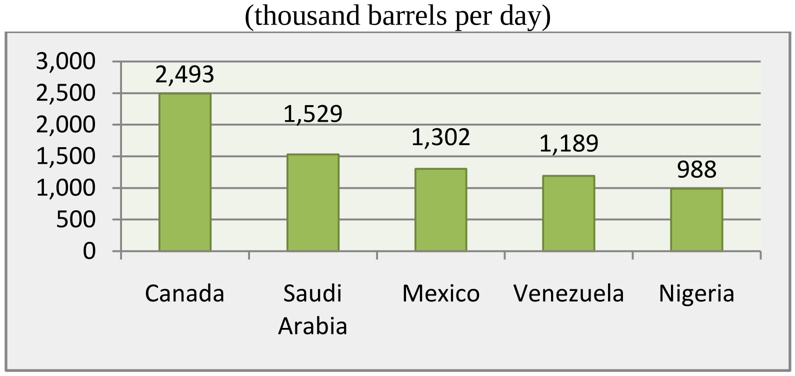
Figure 29: Oil Imports to the United States by country, 1990-2008
(thousand barrels per day)



Source: EIA Petroleum Navigator

have become increasingly scarce as many energy-rich countries have either nationalized the energy sector or have attempted to marginalize the stakes of foreign energy firms operating in their territories. With the largest natural gas reserves and the eighth largest oil reserves [CIA World Factbook: Russia], Russia became a much sought after market for foreign energy firms after the fall of communism. During Vladimir Putin's time in power, however, Russia has sought to consolidate its control over the energy industry. In 2006 Royal Dutch Shell was forced to sell its stake in the Sakhalin-2 oil and gas fields to state-owned Gazprom for alleged environmental breaches while BP was forced to sell its stake in the Kovytka gas field to Gazprom in 2007 for less than market value [Cohen, 2007]. These in state interventions have made Russia an unreliable country within which to make significant investments. Such interventions are highly unlikely to occur in Canada where investment agreements are respected because they are seen as necessary to safeguard the reliable exportation of crude oil and petroleum products to the American market. Furthermore, America's oil security is additionally enhanced from high levels of Canadian oil imports as a result of the two countries agreeing to the Canada-U.S. Free Trade Agreement (FTA) in 1987 and the subsequent North American Free Trade Agreement (NAFTA) of 1994. NAFTA ensures that no party can "adopt or maintain any duty, tax or other charge on the export of any energy or basic petrochemical good" [NAFTA article 604] nor can any party "adopt or maintain a measure restricting imports of an energy or basic petrochemical good" [NAFTA article 607] to another NAFTA country. Since Canada is required to sell petroleum at market prices and cannot restrict oil exports to NAFTA signatories, the United States would be well advised to do what it can to increase imports of oil from Canada. Unlike oil shipments from other countries which can fluctuate due to the internal politics or geopolitical considerations of the exporting nations, oil shipments from Canada are protected by law and are guaranteed to increase so long as overall oil production continues to increase and pipelines are built. More details on the Canadian petroleum industry, including forecasts and challenges to 2030, are presented in Chapter 4.

Figure 30: Top Sources of U.S. Petroleum Imports in 2008 (thousand barrels per day)



Source: EIA Country Analysis Briefs: Canada

3.3 Projections of American Oil Consumption, Production and Imports to 2030

The past several years have greatly altered the projections of American energy supply and demand by the year 2030. Throughout the 20th century and into the first decade of the 21st century oil was the primary energy source which fuelled the growing American economy. As described above, the situation progressively became more unsustainable; as domestic oil production continued to decrease oil imports increased out of necessity. Through a series of legislative changes explored below, the United States can improve its energy security from 2007 to 2030. Specifically, through the Energy Independence and Security Act of 2007 (EISA) and a more stringent Corporate Average Fuel Economy (CAFE), oil consumption will cease climbing and remain at 2008 levels. Furthermore, the expiry of offshore drilling bans in 2008 gives the United States the potential to increase domestic oil production for the first time since 1970.

Moving forward the American economy will become far less dependent on oil imports from unstable foreign countries and will be more insulated from potential supply disruptions.

3.3.1 Energy and Security Independence Act

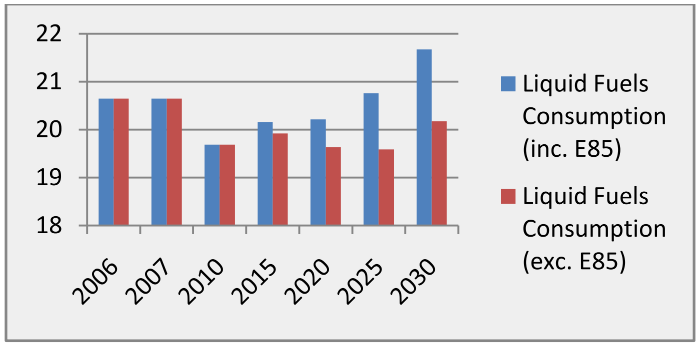
As the largest consumer of oil in the world the United States has long been conflicted on the issue of curbing oil consumption and reducing greenhouse gases. With uses in the industrial and commercial sectors, and most importantly in transportation, oil has become intricately linked to the American economy. Political leaders have thus been loath to sign any agreements restricting oil consumption fearing that to do so would be economically disastrous. One such international agreement is the Kyoto Protocol of 1997. This protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is a binding agreement by industrialized nations to reduce greenhouse gas emissions in order to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" [UNFCCC article 2]. Greenhouse gases are primarily generated through the burning of fossil fuels such as oil, coal, and gas, and therefore by limiting greenhouse gas emissions the protocol would force the United States to limit the consumption of fossil fuels. The vast volumes of oil consumed in the U.S. have contributed to the United States becoming the largest emitter of greenhouse gases in the world, responsible for almost a quarter of total emissions [American Society of International Law, 2001]. The Kyoto protocol targets would have thus been more difficult for a carbon-intensive country such as the United States to reach and so despite signing the protocol on November 12, 1998 it was never ratified by the American government. From early in the process the protocol faced American resistance on a number of issues including the use of market-based approaches to emissions trading, the means for counting carbon sinks as well the means for addressing non-compliance by a signatory. [American Society of International Law, 2001]. However it is clear that the main American disagreement with the protocol is that none of the targets are binding on developing nations, specifically China and India, and that it places an unacceptable cost on the American economy [Sanger, 2001 and Revkin, 2005]. For several years thereafter it seemed as though the United States would not sign any agreement that would force a change in behaviour and the increasing consumption of oil would continue unimpeded. However new legislation introduced over the past couple of years will limit American oil consumption and encourage growth in renewable energies.

The Energy Independence and Security Act of 2007 (EISA) "consists mainly of provisions designed to increase energy efficiency and the availability of renewable energy" [Sissine, 2007]. The 4 main provisions of the Act are; the Corporate Average Fuel Economy (CAFE), the Renewable Fuels Standard (RFS), energy efficiency equipment standards, and the repeal of oil and gas tax incentives. These provisions aim to limit energy consumption by instituting incentives for conservation and setting new efficiency standards across all sectors; residential, commercial, industrial and transportation. However, in order to wean the American economy off excessive oil consumption it is the transportation sector that will need to exhibit the greatest amount of change. Globally the transportation sector was responsible for 61.2% of total global oil consumption in 2007 [IEA Key World Energy Statistics, 2009] and the percentage is even greater in the U.S. where the transportation sector accounts for approximately two-thirds of oil consumption [EIA Oil Demand]. The transportation industry uses a number of different fuels from diesel to jet fuel to residual fuel oil, however gasoline is by far the most important fuel and accounts for approximately two-thirds of the oil used in transportation [EIA Oil Demand]. As the primary fuel used in the sector that accounts for the majority of oil, gasoline is therefore the primary petroleum product consumed in the United States making up roughly 44.5% of total oil consumption. As such, any government Act with the stated aim of reducing total oil consumption and GHG emissions would thus need to curb the consumption of gasoline. The newly revised CAFE standards have been established to accomplish just that. The new CAFE standards have set a target of 35 miles per gallon (6.72 liters per 100 kilometers) for the combined fleet of cars and light trucks for every auto manufacturer by the year 2020 in addition to establishing a fuel economy standard for medium- and heavy-duty trucks. This is a substantial improvement over current fuel efficiency standards which have not been revised since 1990 when the passenger car standard was set at 27.5 mpg (8.55 l/100km). Federal agencies also fall within the scope of the stricter CAFE standards;

they must decrease annual petroleum consumption by 20% and increase their consumption of alternative fuels by 10% over 2005 levels by 2015 [Sissine, 2007]. Furthermore, Federal agencies are forbidden from acquiring any vehicle that is not a "low greenhouse gas emitting vehicle" as is defined under the new Act. Further reductions in petroleum consumption will be made by replacing gasoline with renewable fuels as set forth by the Renewable Fuel Standard (RFS). The RFS sets minimum levels of renewable fuel that must be used in transportation, starting at 9 billion gallons (34 billion litres) in 2008 and increasing to 36 billion gallons (136 billion litres) by 2022 [Sissine, 2007]. This target is to be met through the use of advanced biofuels, specifically cellulosic ethanol and other feedstock biofuels not derived from cornstarch. In 2008 the EISA was further reinforced by the passing of the Energy Improvement and Extension Act of 2008 (EIEA). In addition to providing incentives to increase the use of renewable energies and energy efficient appliances, the EIEA provides tax incentives to purchase plug-in hybrid electric vehicles (PHEV) and to further increase the use of biofuels. The EISA, EIEA and the new CAFE standards are expected to change the types of vehicles sold and will have a significant impact on the consumption of gasoline, and therefore oil. In 2030 60% of all new light-duty vehicles sold in the United States will be low-emission cars such as conventional hybrids, plug-in electric hybrids (PHEV) or will be equipped with E85 flex-fuel technology[12]. [EIA Annual Energy Outlook, 2009] Due in part to higher sales of these more fuel efficient vehicles the consumption of petroleum-based motor fuels is projected to decline by 1.3 million barrels per day by 2030, a significant reduction. Although the quantity of gasoline and other petroleum-based motor fuels will decline, total liquid fuels[13] consumed for transportation will be greater by approximately 1.7 million barrels per day in 2030 than in 2007. [EIA Annual Energy Outlook, 2009] The reduction in gasoline will be more than replaced by the growth in diesel fuel and biofuels, each of which will be consumed at a rate 1.5 Mb/d greater day higher than in 2007 [EIA Annual Energy Outlook, 2009], see Figure 31.

[12] E85 flex-fuel cars run on fuel which is compose of 85% ethanol and 15% gasoline
[13] Liquid fuels refers to oil, diesel , ethanol, biodiesel and other biofuels.

Figure 31: Expected Change in Liquid Fuels Consumption (Mb/d)

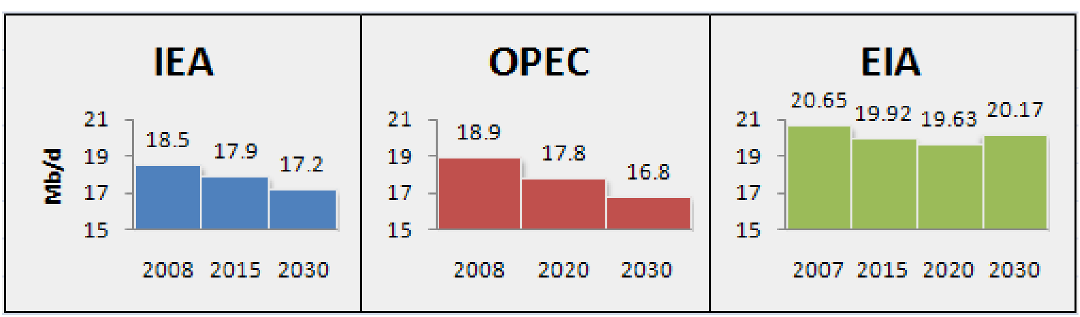


Source: EIA Annual Energy Outlook, 2009

3.3.2 Projection of American Oil Consumption

Reductions in oil consumption are expected in other sectors of the American economy as well. The use of oil in the generation of electricity will decline over time as overall electricity demand is expected to grow slowly. Electricity generation from existing oil-fired plants will be offset by the growth in electricity generation from new plants using coal, natural gas, nuclear and renewable fuels while little new oil-fired capacity will be installed. Oil will be increasingly displaced as a fuel for heating buildings and will be used in lower quantities in industry as energy efficiencies improve. The conclusion to be drawn is that the EISA and EIEA will have a considerable impact on American oil consumption; total consumption in 2030 will be less than or equal to 2008 levels [IEA World Energy Outlook, 2009, OPEC World Oil Outlook, 2009, EIA Annual Energy Outlook, 2009], see Figure 32.

Figure 32: Various American Oil Consumption Projections to 2030



Sources: IEA World Energy Outlook, 2009, OPEC World Oil Outlook, 2009, EIA Annual Energy Outlook, 2009[14]

[14] EIA figures include oil products such as lubricants, waxes, asphalt, special naphthas and miscellaneous petroleum products

3.3.3 Projection of American Oil Production

Declining future oil consumption is but one of the factors that will serve to improve American oil security. Another important variable is the ability of domestic oil production to expand and its capacity to meet demand. As shown earlier in this chapter, American oil consumption rapidly increased through the latter half of the 20th century despite declining domestic oil production. Oil production was seen to have peaked in 1970 at a level of 9.637 Mb/d and has steadily declined until production reached approximately 4.95 Mb/d in 2008. The declining trend in Figure 3 is clear and it would be logical to assume that future production will continue to decline at a similar rate to the past several decades. Future production, however, will see a reverse in the trend as future production will remain flat with the possibility that it may even increase. OPEC for example, believes American oil production will remain flat until the year 2016 as new deepwater production from of the Gulf of Mexico comes on-line. This production is projected to offset the decline from the oil fields in Texas, California, Alaska and the shallower Gulf of Mexico fields [OPEC World Oil Outlook, 2009]. After 2016 OPEC believes that production will again continue its historical decline and by 2030 oil production will be 1 Mb/d lower than in 2016. This is seen as a conservative estimation, the OPEC projection does not take into account potential production from the Outer Continental Shelf (OCS), offshore fields in the Atlantic, Pacific and Gulf of Mexico which had been under federal exploration bans until 2008. Further production gains will be realized through the application of new Enhanced Oil Recovery (EOR) technologies which will increase recovery from both new and old oil fields.

Offshore oil production has faced stiff resistance since the 1960s. Oil production off the coast of southern California was set to take off towards the end of the decade when disaster struck in 1969: due to a geological anomaly 6000 barrels of crude oil leaked into the sea and washed up on California beaches [Yergin, 1991]. This environmental disaster created a nationwide outcry against offshore drilling and forced President Richard Nixon to place a moratorium on drilling of the California coast [Yergin, 1991]. Since 1982 Congressional and Executive bans on offshore drilling have been extended to the OCS. From that year up until 2008 Congress annually enacted appropriation riders which prohibited the exploration and production of oil and natural gas on most of the OCS. In 1990 President George H.W. Bush further supported this action of Congress by signing an executive ban that prohibited leasing on the OCS in the Atlantic and Pacific coasts as well as in parts of the Eastern and Central Gulf of Mexico. The executive ban was then extended until 2012 by President William Clinton [EIA Annual Energy Outlook, 2009]. All of the obstacles to exploration and production in the OCS, however, were removed in 2008 when Congress allowed the congressional ban to expire and when President George W. Bush lifted the executive ban 4 years before it was set to expire. Lifting the executive ban makes blocks in the Atlantic and Pacific OCS available for leasing of 2010 with parts of the Eastern and Central Gulf of Mexico available for leasing in 2022. This is an important development for the American oil industry because the areas previously under the ban are believed to contain vast amounts of oil and natural gas deposits that would enable domestic oil production to increase for the first time since 1970. The total technically recoverable resources in the OCS are estimated at 93.31 billion barrels of oil (see Figure 33), an amount more than 4 times as large as the remaining US proven oil reserves[15] [EIA Annual Energy Outlook, 2009]. Proven resources may end up being less than the 93 billion barrels however many geologists are quite certain that these areas will prove to be fruitful in the coming years.

Although the barriers to exploration and production in the Atlantic and Pacific have been removed it will take several years before oil production from these areas is realized. Well before production starts block leases must be bid on by oil companies and awarded by the Minerals Management Service (MMS) of the U.S. Department of the Interior, a process that can take up to a year or two. From there the companies that were awarded blocks must present detailed exploration and development plans for approval from the MMS before starting exploratory drilling. Exploratory drilling can take anywhere from 1-3 years for a project in shallower waters to up to 6 years in deep water [EIA Annual Energy Outlook, 2009]. A further 1-3 years is then required for development drilling which means that the whole process, from bidding on blocks

[15] EIA estimates proven American oil reserves in 2009 equaled 21.317 billion barrels [EIA Petroleum Naviagator]

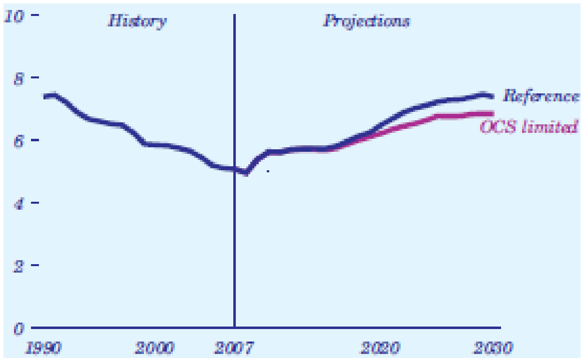
Figure 33: Outer Continental Shelf Technically Recoverable Resources, January 1, 2007

Resource area and category	Crude oil (billion barrels)	Natural gas (trillion cubic feet)
Undiscovered resources		
Gulf of Mexico	*34.29*	*183.21*
Eastern and Central Gulf of Mexico (earliest leasing in 2022)	*3.65*	*21.46*
Pacific (earliest leasing in 2010)	*10.50*	*18.43*
Atlantic (earliest leasing in 2010)	*3.92*	*36.50*
Alaska	*26.61*	*132.06*
Total undiscovered	***78.97***	***391.66***
Proved reserves		
Gulf of Mexico	*3.66*	*14.55*
Pacific	*0.44*	*0.81*
Atlantic	*0.00*	*0.00*
Alaska	*0.03*	*0.00*
Total proved reserves	***4.13***	***15.36***
Inferred reserves		
Gulf of Mexico	*9.33*	*48.83*
Pacific	*0.89*	*0.26*
Atlantic	*0.00*	*0.00*
Alaska	*0.00*	*0.00*
Total inferred reserves	***10.21***	***49.09***
Total OCS resources	***93.31***	***456.11***

Source: EIA Annual Energy Outlook, 2009

to production can be expected to take from 4-12 years. Therefore leases which are awarded in 2010 can be expected to come on-line anywhere from 2014 in the best case scenario to 2022 for deepwater projects. These factors have been included in the EIA's projection of U.S. oil production which is believed to start increasing in 2009 and continue to do so until 2030, see Figures 34 and 35 below. The reference case scenario does come across as quite optimistic, however. Offshore oil drilling will continue to face vocal opposition from environmental groups and has been a delicate subject in American domestic politics. If there happens to be an oil spill any time over the next 20 years, be it in the United States or anywhere else on the globe, it would give opponents of offshore drilling the perfect pretext to halt further development. Accordingly, it seems more prudent to use the numbers for the OCS limited scenario to prepare for the future. Under the OCS scenario American domestic production rises to 6.21 Mb/d in 2020 and modestly increases to 6.83 Mb/d.

Figure 34: Projected total domestic oil production in the United States up to 2030 (Mb/d)



Source: EIA Annual Energy Outlook, 2009

Figure 35: Figures of projected domestic crude oil production in 2020 and 2030

Projection	Crude oil production (million barrels per day)
2020	
Reference case	6.48
OCS limited case	6.21
Difference from reference case	-0.27
Percent difference from reference case	-4.2
2030	
Reference case	7.37
OCS limited case	6.83
Difference from reference case	-0.54
Percent difference from reference case	-7.4

Source: EIA Annual Energy Outlook, 2009

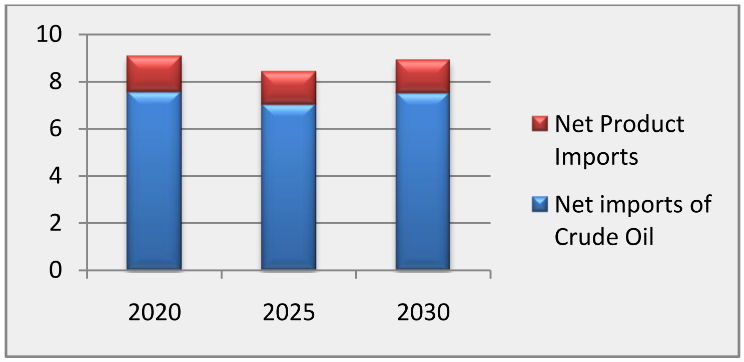
The implications for American oil security from increasing domestic production are significant. With consumption decreasing and production slightly increasing, fewer imports will be required over the projected period. In 2020 the United States will need to import roughly 9.05 Mb/d of crude oil and other oil products[16], a number that drops to 8.39 Mb/d in 2025 before a slight climb to 8.49 Mb/d in 2030, see Figure 36. If these trends hold true by 2030 the United States will be importing almost 4.5 Mb/d less than in 2008. Oil security will be further enhanced by the fact that over this same period of time Canada will be producing substantially more oil than at present enabling exports to rise.

Canadian production of oil will increase by almost 2 Mb/d between 2008 and 2030. Unlike with the conventional sources of crude oil found in the Middle East, expanding production in Canada is a far more difficult proposition. Out of the 178 billion barrels of proven oil reserves in Canada, 173 billion barrels are trapped in the oil sands of Alberta. Oil from the oil sands is much more difficult to extract, requiring large inputs of water and natural gas in order to produce a usable commodity. The oil sands also face opposition from groups who fear rapid expansion of oil production will lead to serious environmental and human rights problems (see Chapter 4 for greater detail of the Canadian oil industry). Production expansion will therefore be slower than is possible in conventional oil fields. Nonetheless, oil production will increase from 2.6

[16] Other products include: Gross Refined Products, Unfinished Oil, and Blending components. [EIA International Energy Outlook 2009]

Mb/d in 2008 to over 5 Mb/d by 2030 [EIA International Energy Outlook, 2009, OPEC World Oil Outlook 2009]. With Canadian oil consumption not projected to increase over this time, Canada will have the capacity to increase oil exports to the United States

Figure 36: Estimated Future U.S. Import Requirements (Mb/d)



Source: EIA Annual Energy Outlook, 2009

from 1.956 Mb/d to nearly 4 Mb/d between 2008 and 2030. Factoring in refined oil products, Canadian exports may exceed 4 Mb/d in which case Canada would be supplying the United States with more than 45% of its oil imports. In such a scenario American oil supply security is much improved. Canada is ranked as the most secure oil producing country in the world according to the Energy Security Index because of a lack of government interference in the energy industry and its ability to safely transport oil. Oil is transported to American refineries via pipelines which are much more secure than shipping oil by tankers. Oil tankers have recently become targeted by pirates in the Gulf of Aden and can also be affected by adverse weather conditions. Geopolitics can also affect oil shipments by sea. A case in point is the Strait of Hormuz where 40% of world's oil must pass through [DeBard, 2009]. Iran controls this strait and could choose to close this strait for any number of reasons. For the United States this would cut off their imports from Saudi Arabia, Iraq, Kuwait, and the United Arab Emirates whose combined supply to the U.S. amount to 2.37 Mb/d in 2008 [EIA Petroleum Navigator]. The United States would not need to struggle in a battle versus China and India to secure oil supplies agreements from unstable regimes. Furthermore, increasing oil imports from Canada the United States will be able to improve its profile internationally. While not yet energy independent, America's position in 2030 will be much better than it has been since the first half of the 20th century.

CHAPTER 4: CANADA AND THE OIL SANDS

With the second largest land mass of any nation in the world Canada has been endowed with vast amounts of natural resources which it has utilized to become one of the largest energy producers in the world. Canada is the world's third largest producer and second largest exporter of natural gas, the sixth largest producer of electricity, and the seventh largest oil producer [CIA World Factbook: Canada]. With the second largest oil reserves in the world, Canada is poised to become a more prolific producer of oil and petroleum products over the next 20 years. Compared to other oil exporting countries Canada's oil industry is still in its infancy due to the complexities involved in producing crude oil from the oil sands of Western Canada. Despite these difficulties Canada has already surpassed Saudi Arabia as the largest supplier of foreign oil to the United States. Further technological improvements and more investment are needed for Canada to expand production over the next couple of decades in order to supply and even larger percentage of American oil needs. With a stable, democratic government and strong economy, Canada presents international oil companies with an ideal investment climate. This development will further deepen the economic and political ties between the North American neighbours and the United States will use greater volumes of Canadian oil to strengthen its oil supply security. Global oil reserves will decline over the next couple of decades and oil production will become increasingly concentrated in fewer countries, this will exacerbate oil supply security issues for oil importing nations. Due to the nature of its oil reserves, producing crude oil in Canada presents greater challenges than in the traditional oil regions of the world. Producing oil in Canada is more costly in both monetary and in environmental terms and opposition to expansion of oil sands projects has been steadily growing. Canada, however, will overcome these challenges and see its oil production expand substantially over the next 20 years and further consolidate its position as the largest oil supplier to the United States.

4.1 Canadian Oil Reserves:

Large scale oil production first began in the mid-19th century in the American state of Pennsylvania. American oil production dominated until the epicentre of the global oil industry shifted to the Middle East in the mid-20th century with the discovery of the enormous oil fields of Burgan and Ghawar in Kuwait and Saudi Arabia, respectively. New oil discoveries which increased American oil reserves from 21 billion barrels to 38 billion barrels between 1948 and 1972, American reserves as a percentage of total global reserves fell from 34% to 7% during that time period [Yergin, 1991]. The reason for this drop was the increase of proven Middle Eastern oil reserves grew from 28 billion barrels to 367 billion barrels. The reported reserves in the Middle East continued to grow and in 2002 the top five countries with the largest reserves were from the Middle East, see Table 2. Total Middle Eastern reserves were estimated to be 685.59 billion barrels, a staggering 66% of total world oil reserves. [EIA International Energy Statistics] At the end of that same year, however, a simple change transformed Canada from a fringe player in the world oil market to the country with the second largest oil reserves in the world. In 2002 Canada's reserves, as estimated by the Oil and Gas Journal, were 4.9 billion barrels. At the end of the year the Oil and Gas Journal changed its methodology and as a result the oil sands were no longer classified as "unconventional oil". This change in methodology increased Canada's oil reserves from 4.9 billion barrels to 180 billion barrels overnight and in the process it cut OPEC's share of world oil reserves by 10% [McColl, 2008]. Most other reserve estimates followed suit and since 2003 Canada has been listed as the country with the largest reserves behind Saudi Arabia (see Table 3**)**.

Table 2: Oil Reserve Estimates, 2002

Country	Oil Reserves (Gb)
1) Saudi Arabia	261.75
2) Iraq	112.5
3) UAE	97.8
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34) Canada	4.86

Source: EIA International Energy Statistics

Table 3: Oil Reserve Estimates, 2003

Country	Oil Reserves (Gb)
1) Saudi Arabia	261.8
2) Canada	180.021
3) Iraq	112.5
4) UAE	97.8
5) Kuwait	96.5

Source: EIA International Energy Statistics

There are three predominant oil producing regions in Canada; the Western Canada Sedimentary Basin (WCSB)[17], offshore of Newfoundland and Labrador, and the oil sands in Alberta. Canada's oil reserves are spread unevenly among the three regions with the oil sands in Alberta containing the vast majority of total reserves. Offshore reserves are currently estimated to be 1.02 billion barrels, while the WCSB is estimated to contain another 2.85 billion barrels [NEB 2009 reference case scenario]. It is possible that future discoveries in these regions will be made but it is not believed that a giant oil field will be found. Large oil reserves, estimated at 90 billion barrels [USGS Circum Arctic Appraisal], are thought to exist within the Arctic Circle. These reserves, however, are not yet accessible due to environmental conditions. Furthermore, jurisdiction over Arctic resources is being contested by several nations including Canada, Russia, Norway, Denmark and the United States. Even without this potential new source of oil, Canada has enormous proved reserves in the oil sands. Located near the town of Fort McMurry, Alberta the oil sands contain approximately 173 billion barrels, or 96% of total Canadian oil reserves. With reserve estimates constantly being revised due to technological advances, the market price of crude oil, and political factors, it is difficult to know what the ultimately recoverable amount of oil will be. Some estimates have put the number of ultimately recoverable crude oil from the oil sands at around 315 billion barrels [NEB Canada's Oil Sands, 2006]. Although it took many years for production from the oil sands to reach commercial levels, production from the WCSB and offshore have already matured and thus any future increases in Canadian oil production will come solely from the oil sands.

The Oil & Gas Journal changed their methodology in 2002 to include oil sands as a "conventional" source of oil, however oil sands are among the sources of crude oil that are still often referred to as "unconventional". It is difficult to make a clear distinction between what constitutes a "conventional" source and an "unconventional" source since there does not exist any single accepted definition of these terms. Often the criterion for conventional crude oil is done in terms of viscosity; the Association for the Study of Peak Oil and Gas (ASPO), for example, classify oil with a viscosity above

[17] The WCSB lies under the provinces of Alberta, British Colombia, Saskatchewan, Manitoba and the Northwest Territories

17^0API as being conventional [EWG, 2007]. Sometimes a more pragmatic definition is also used whereby conventional oil includes crude oil with a viscosity greater than 17^0API, heavy oil with a viscosity between 10-17^0API, all deep sea oil, polar oil and condensate. Even this definition is too restrictive since it requires that a source of oil fall into one of those categories in order to be labelled "conventional". Whether or not a source of oil is conventional is geological terms is irrelevant and the "exclusion of developed commercial, non-conventional oil from reserves, because of the quality or method of extraction...seems rather illogical" [Haider, 2000]. It is most reasonable, therefore, to accept the economic definition of conventional oil: "oil which can be produced with current technologies under present economic conditions" [EWG, 2007]. Oil sands are referred to as unconventional because unlike the sweet light crude oil which bursts out of the ground in the Middle East, the oil sands consist of a thick, naturally occurring mixture of sand, minerals, water and bitumen. Bitumen is a "heavy, viscous oil that must be processed extensively to convert it into a crude oil before it can be used by refineries to produce gasoline and other petroleum products" [CAPP, 2009]. At room temperature bitumen has the consistency of molasses and needs to be diluted with a light hydrocarbon liquid in order to transport it through pipelines, see Annex 4 for a picture of unprocessed oil sand. Regardless of classification, production from the oil sands contributed to Canada becoming the seventh largest producer of oil and will be the source of future production growth.

4.2 Current Production, Consumption and Exports of Canadian Oil

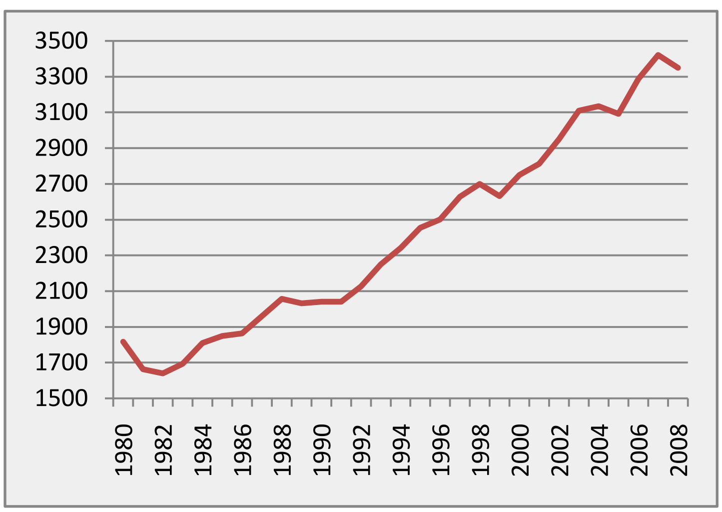
Oil production in Canada has grown more than twofold in the past 30 years. Total Canadian oil production[18] increased at the steady rate of 2.5%, from 1.662 Mb/d in 1981 to over 3.35 Mb/d in 2008, see Figure 37 [EIA International Energy Statistics]. This current rate of production places Canada as the seventh largest oil producer in the world, producing 3.9% of the total output of world oil (see Table 4**)**. The WCSB has traditionally been the source for the majority of Canadian oil production however most of the fields in the WCSB are now mature and starting to decline in production. In 1999 65% of Canadian production came from the WCSB, a Figure that has since fallen

[18] The production of crude oil including lease condensate, natural gas plant liquids, and other liquids, and refinery processing gain

to 39% as bitumen production from the oil sands started to replace the conventional supply [EIA Country Analysis Briefs: Canada]. Production from fields offshore Newfoundland and Labrador totalled approximately 368,000 barrels per day in 2008, however these fields are also thought to be in decline [EIA Country Analysis Briefs: Canada]. This region is still being explored for additional oil reserves and Atlantic oil production is expected to be given a boost when heavy oil production from the Hebron field comes on-line in 2017 [CAPP, 2009]. Despite this potential boost from the Hebron field, the offshore and WCSB regions are in terminal decline and do not offer any prospects for expanding future oil production.

Unlike the other oil producing regions the oil sands are far from maturing and the growth of output can only be constrained by a lack of investment. The technological challenges of separating bitumen from the oil sands mixture prevented commercial production until 1967. The first oil sands operation was undertaken by the Great Canadian Oil Sands ltd and it took them until the year 2000 to reach a production

Figure 37: Canadian Oil Production 1980-2008 (thousand barrels per day)



Source: EIA International Energy Statistics

Table 4: Top Oil Producing Countries (Million tons, Mt)

Producers	Mt	% of world total
Saudi Arabia	509	12.9
Russian Federation	485	12.3
United States	300	7.6
Islamic Rep. of Iran	214	5.4
People's Rep. of China	190	4.8
Mexico	159	4.0
Canada	155	3.9
Kuwait	145	3.7
Venezuela	137	3.5
United Arab Emirates	136	3.5
Rest of the world	1 511	38.4
World	3 941	100.0

2008 data

Source: IEA Key World Energy Statistics 2009

level of 600,000 barrels per day [CERA Growth in the Canadian Oil Sands, 2009]. Production has dramatically increased since the year 2000 as extraction techniques improved and investments increased. In 2009 1.3 Mb/d were produced from the oil sands, more than double the 2000 level [CERA Growth in the Canadian Oil Sands, 2009]. One of the technological advances in extraction that enabled production to increase is *in situ*[19] production (see section 4.3 for details of *in situ* extraction). When commercial production from oil sands first began, bitumen was extracted using open-pit mining, a method still responsible for 55% of the total oil sands output [CERA Growth in the Canadian Oil Sands, 2009]. The largest oil sands projects remain the mining operations, like the Canadian Oil Sands ltd Syncrude Project which produced 290,000 bb/d in 2008, and the Suncor mine which produced 228,000 bb/d in the same year [EIA Country Analysis Briefs: Canada]. The *in situ* projects outnumber mining operations but they are smaller in scale. The largest of the *in situ* projects is the Cold Lake facility which is operated by Imperial Oil (a subsidiary of ExxonMobil) and has a production capacity of 150,000 bb/d. Although the *in situ* projects are currently smaller in scale large expansions are foreseen. Open-pit mining is very limited because only 20% of the oil sands are shallow enough to be mined with the remaining bitumen only accessible by using *in situ* technology.

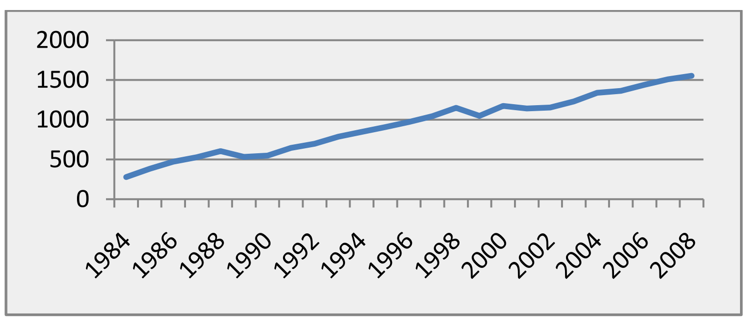
As Canada's oil production increased over the past decade so did its exports. From 1984 to 2008 Canadian crude oil exports increased more than fivefold, from 277,000 b/d to 1.55 Mb/d (see Figure 38**)**. Canada's refining capacity also enables Canada to export many other petroleum products such as gasoline and petrochemicals. The United States is the most logical export market for Canadian oil due to geographical proximity and the existence of a large network of pipelines and presently receives 99% of all Canadian oil exports [EIA Country Analysis Briefs: Canada]. The United States is linked to Canada's oil industry through six export pipelines: the Enbridge, Kinder Morgan Express, Kinder Morgan Transmountain, Milk River, and Rangeland pipelines. These pipelines have a total capacity of 2.6 Mb/d [McColl, 2008] and are being used near this maximum rate. Exports grew over the past decade to the point where Canada is now the largest foreign supplier of oil to the US providing 19% of total petroleum imports at a rate of 2.46 Mb/d in 2008 [CERA Growth in the Canadian Oil Sands], see Table 5. Oil exports to the United States are not spread equally among the 50 states and vary greatly between the five so-called Petroleum Administration for Defence Districts (PADD). The continental United States was

[19] *In situ*: Latin phrase meaning "in place"

divided into five PADDs during the Second World War to better organize fuel rationing throughout the country and this delineation is still used in the American oil industry today [CAPP, 2009]. The majority of Canadian oil exports are sent to PADD II, the region south-east of the oil sands which is linked to Alberta through several pipelines including the Enbridge Spearhead and MinnCan pipelines [CAPP, 2009]. Of the 2.436 Mb/d produced in Western Canada in 2008, 47.4% was shipped to PADD II (see Annex 4 for a detailed map of oil exports to each PADD [CAPP, 2009]. None of the other PADD regions are currently receiving large quantities of oil from western Canada, but this is a situation which will change in the future as oil sands production and exports continue to rise.

The large volume of oil exports to the United States would suggest Canada is solely an exporter. The eastern provinces of Canada, however, import a sizeable volume of oil from Saudi Arabia and the United Kingdom. This is because the provinces east of Ontario are not connected via pipeline to the oil fields in Alberta. Over the same period of time that Canadian oil exports

Figure 38: Canadian Exports of Crude Oil 1984-2008 (thousand barrels per day)



Source: EIA International Energy Statistics

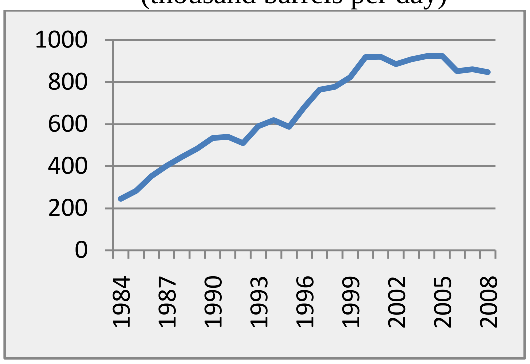
Table 5: Top Sources of American Oil Imports Figure 38:

Country	Share of Total U.S. Imports
Canada	19%
Saudi Arabia	12%
Mexico	10%
Venezuela	9%
Nigeria	8%

Source: CERA Growth in the Canadian Oil Sands, 2009

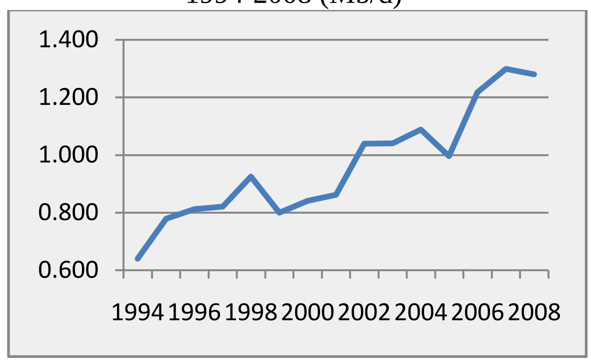
were increasing, as shown in Figure 37, so too were Canadian crude oil imports. Crude oil imports steadily increased from 244,780 b/d to 920,000 b/d between 1984 and 2001 before levelling off (see Figure 39**)**. In 2008 Canadian crude oil imports totalled 847,000 b/d [EIA International Energy Statistics]. Taking imports of crude oil and other petroleum products into account Canada remains a net exporter of oil (see Figure 40**)**. The Eastern provinces seem set to remain oil importers into the foreseeable future as production from the Atlantic fields decline however western crude oil may begin to flow into Quebec if Montreal-to-Sarnia pipeline is reversed [CAPP, 2009].

Figure 39: Canadian Crude Oil Imports (thousand barrels per day)



Source: EIA International Energy Statistics

Figure 40: Canadian Net Export of Oil 1994-2008 (Mb/d)



Source: EIA International Energy Statistics

4.3 Oil Sands Production Techniques

The Canadian oil sands have been recognized as a potential source of recoverable crude oil since before the 20th century. Geologist Robert Bell first speculated that huge oil deposits may exist in the Alberta oil sands in 1884, what was not immediately clear was how to separate the bitumen from the sand, clay and other impurities. Dr. Karl Clark, a chemist working for the Alberta Research Council, was the first person to develop a method to isolate bitumen by saturating the oil sands with hot water, steam and caustic soda in a rotating drum [CERA Growth in the Canadian Oil Sands, 2009]. Dr. Clark's breakthrough method occurred in 1920 but it would take several more decades before the method was sufficiently refined in order to make it commercially viable. Commercial production eventually began when the Great Canadian Oil Sands ltd opened the first open-pit mining project in 1967.

Unlike most sources of conventional oil which lie underground and can only be accessed through drilling, the oil sands are relatively shallow and significant volumes of oil can be collected through open-pit mines. This method, similar to traditional forms of open-pit mining, begins by clearing the overburden; the grass, trees and other vegetation which lie on the surface. Once the overburden has been removed, large mechanical shovels dump the raw oil sand onto massive 400-ton trucks which then transport the oil sands to a facility where the bitumen is separated from water, clay, sand and other minerals. The separated bitumen is then sent to an upgrader, a facility where bitumen is refined into a usable product or is diluted for transportation by pipeline. The process is quite laborious as it takes approximately 2 metric tons of mined oil sands to produce 1 barrel of oil [CERA Growth in the Canadian Oil Sands, 2009]. Nonetheless this method still accounts for 55% of the 1.3 Mb/d which were extracted from the oil sands in 2008 [CERA Growth in the Canadian Oil Sands, 2009].

New extraction technologies were required in order to reach the 80% of recoverable oil sands not accessible through open-pit mines. The solution was to inject steam directly into the ground making the bitumen less viscous so that it can be pumped to the surface. Two similar methods are used: Cyclic Steam Stimulation (CSS) and Steam Assisted Gravity Drainage (SAGD). Initially developed in the 1950s, CSS technology was commercialized by 1985 [McColl, 2008]. The extraction process takes place in several stages. The first stage involves injecting steam into the ground at a temperature of 300^{0}C and at a pressure averaging 11,000 kilopascals for several weeks [McColl, 2008]. The steam injection is then stopped and the bitumen is pumped to the surface until the ground temperature falls to a lower boundary where extraction rates decline; at this point the process is re-started with the steam injection [North Peace Energy]. SAGD is a more recent technology. It was developed during the late 1970s and early 1980s and is a more continual process than CSS [McColl, 2008]. SAGD involves drilling two horizontal pipes 200m under the ground, one pipe above the other. The upper pipe injects steam into the ground and as the bitumen softens it trickles down to the second pipe which pumps it to the surface for processing. (See Annex 4 for diagrams of each method) *In situ* methods have several advantages over open-pit mining. Many pipes can be drilled into the ground under the same facility thus disturbing less of the ground surface. Additionally, recovering the bitumen using either SAGD or CSS does not require the construction of tailings ponds, an environmentally hazardous by-product of the separating facilities in mining operations (for details see section 4.4.2). The two methods generated approximately the same output of 200,000 barrels per day in 2007 [CERA Growth in the Canadian Oil Sands, 2009], however SAGD is projected to provide more of the oil supply growth in the future due to a number of advantages over CSS [NEB Canada's Oil Sands, 2006]. One advantage with SAGD is that it is a much more efficient process with a recovery factor of 50% compared to the 15-20% for a CSS operation [McColl, 2008]. The most important advantage though, as is often the case, is a lower production cost. SAGD requires a lower steam-to-oil ratio[20] which enables it to not only lower water requirements but also to produce bitumen at a lower cost than CSS. Supply costs for SADG are estimated to be in the range of $18-$22 per barrel with capital spending requirements of $15,000 per barrel compared to a supply cost of $20-$24 for CSS and capital spending requirements of $20,000 per barrel [NEB Canada's Oil Sands, 2006], see Table 6 and 7. Due to these advantages production from SAGD in 2008 was slightly higher than from CSS [CERA Growth in the Canadian Oil Sands, 2009] and most new *in situ* projects will use SAGD technology [Humphries, 2007]. Research is being conducted on enhanced SAGD technology which will further lower costs, water requirements and greenhouse gas (GHG) emissions.

Table 6:

Estimated Operating and Supply Costs by Recovery Type

C$(2005) per barrel at the Plant Gate	Crude Type	Operating Cost	Supply Cost
Cold Production – Wabasca, Seal	Bitumen	6 to 9	14 to 18
Cold Heavy Oil Production with Sand (CHOPS) – Cold Lake	Bitumen	8 to 10	16 to 19
Cyclic Steam Stimulation (CSS)	Bitumen	10 to 14	20 to 24
Steam Assisted Gravity Drainage (SAGD)	Bitumen	10 to 14	18 to 22
Mining/Extraction	Bitumen	9 to 12	18 to 20
Integrated Mining/Upgrading	Synthetic	18 to 22	36 to 40

Source: NEB Canada's Oil Sands, 2006

[20] Steam-to-Oil ratio is "the ratio of the volume of steam injected to the volume of bitumen recovered" [McColl, 2008]

Table 7:

Capital Spending Requirement

Project Type	Capex per daily flowing barrel
CSS	$20,000
SAGD	$15,000
Mining & Extraction	$20,000
Upgrading	$32,000

Source: NEB Canada's Oil Sands, 2006

4.4 Environmental Concerns

The production of oil has never been considered to be an environmentally friendly industry. The oil sands, however, pose an even greater challenge to environmental sustainability. The oil sands are located in an area of Canada's expansive boreal forest covering 1.3 billion acres of land which contains vast wetlands filled with wildlife. This northern area of the province of Alberta, hundreds of kilometres from the nearest city, had long been untouched. The recent Canadian oil boom, encouraged by the high price of oil between 2007 and 2009, has altered the landscape as more land leases have been signed and new production facilities have come into operation. Principle environmental concerns include: the disturbance of the ground surface, the formation of tailings ponds, fresh water management, and GHG emissions. Environmental issues are among the greatest challenges which need to be addressed for oil sands production to expand. The oil industry risks provoking public opposition to expansion of oil sands production should their environmental record be less than acceptable. The American oil industry has witnessed the power of public opposition: Atlantic, Pacific and Central Gulf of Mexico offshore oil drilling was prohibited until the year 2008 due to Congressional and Legislative bans following an offshore oil leak in 1969 [Yergin,1991]. Lowering GHG emissions will be particularly crucial for the oil industry as Canada sets new environmental targets following the UN climate summit of 2009 in Copenhagen. Lowering the carbon footprint of bitumen production will also be necessary in order to continue oil exports to the United States as American environmental regulations become stricter. The positive investment climate in Canada along with Federal research subsidies has encouraged technological progress to improve the environmental impact from oil sands production. Technological advances are showing promises in cutting the use of fresh water and lowering GHG emissions while land reclamation projects have demonstrated that disturbed land can be returned to nature. The Federal government of Canada must continue to work with industry and environmental groups to further these advances and apply them in commercial production.

4.4.1 Land Disturbance

Both the mining and *in situ* operations have their environmental shortcomings however the mining operations are particularly destructive to the physical environment. In their application to expand the Muskeg River Mine, Shell Canada Energy states that the expansion will result in "a complete loss of soil and terrain, terrestrial vegetation, wetlands and forest resources, wildlife and biodiversity" during the life of the mine [CERA Growth in the Canadian Oil Sands, 2009]. Removal of the overburden is an unfortunate but necessary requirement to reach the oil sands via open-pit mining. Currently 518 square kilometres of land [CERA Growth in the Canadian Oil Sands, 2009] are disturbed by the open-pit mines with this number certain to grow over the next several years. Imperial Oil's Kearn mine and Petro-Canada's Fort Hills mine are but two of the proposed projects expected to come online over the next decade and while they will combine to add 400,000 b/d of output [CERA Growth in the Canadian Oil Sands, 2009], they will also add to the ecological damage of the area. The nature of open-pit mines is such that during the lifespan of the mine little can be done to make the process more environmentally sound. In comparison, *in situ* facilities are better than the mining operations affecting about 15% of the land disturbed by mining while not producing tailings ponds [Government of Alberta, 2006]. *In situ* facilities, however, require an extensive network of pipes which break-up parts of the forest taking away much of the natural habitat from indigenous animals. In order to restore the natural environment as quickly as possible, the Government of Alberta requires all applications for oil sands operations to include full plans for land reclamation. To ensure compliance the company in charge of a project is obligated by law to post a "financial security equivalent to the cost of reclamation before beginning oil sands activity" [Government of Alberta, 2006]. These funds, totalling $721 million in 2008, are returned to the firm once a land reclamation certificate has been issued by the

Government of Alberta. In spite of the financial security, the pace of land reclamation has been slow with only 1 square kilometre of land certified as being reclaimed [CERA Growth in the Canadian Oil Sands, 2009] with a further 65 square kilometres of land in the process of being reclaimed [Government of Alberta, 2006]. It is estimated that by 2020 a third of all disturbed land will be reclaimed and this projection, in addition to the current figures, are as per the reclamation plans agreed to between government and industry when the projects were originally approved. [CERA Growth in the Canadian Oil Sands, 2009] Sadly the pace of reclamation is constrained by the long lifespan of mines, some of which have been in operation for over 30 years, and the length of time it takes for land to be reclaimed, estimated at 50 years in some cases [Government of Alberta, 2006]. The process of complete land reclamation will take a very long time and environmental groups, along with Federal and Provincials Governments, will need to constantly monitor reclamation efforts to ensure nature is restored as soon as possible.

4.4.2 Tailings Ponds

A further blemish on the Alberta landscape comes from the tailings ponds which contain the waste water from the extraction process. These ponds contain water, sand, clay and other wastes [21] which are left to sit in unlined open-air basins. The waste water is pumped into the basin and settles into three separate layers. The bottom layer is composed of the sand, which quickly settles at the bottom of the pond and acts as a lining to prevent run-off from reaching the river or contaminating ground-water. The middle layer is a mixture of clay, water and silt while the top layer is comprised of water and left over bitumen. The management of the ponds has become a more important issue as mining operations have grown; in addition to the 518 square kilometres of land disturbed by the mines themselves, another 140 square kilometres of land is occupied by tailings ponds [CERA Growth in the Canadian Oil Sands, 2009]. The ponds received national notoriety in the spring of 2008 when a group of 500 migrating ducks landed in Syncrude's Aurora mine tailing pond, which resulted in almost all of them being killed [Brooymans, 2008]. This incident renewed debate over

[21] Other residues include benzene, phenols, toluene, ammonia, arsenic, cyanide and iron [CERA]

the environmental impact of oil sands operations; it should be noted, however, that environmental regulations are improving. In addition to installing noisemakers to scare-off birds, tailings ponds are required to include groundwater monitoring and seepage capture facilities as well as building interceptor ditches to prevent seepage from entering rivers [Government of Alberta, 2006]. In 2008, the Government of Alberta provided $7 million in grants to study the reclamation of tailings ponds [Government of Alberta, 2006] and the National Research Council of Canada (NRC) is researching methods to recover residual bitumen and metals such as aluminum and titanium [Humphries, 2007]. Additionally, the Energy Resources Conservation Board (ERCB), responsible for regulating Alberta's energy development, set a new directive whereby after July 2012 half of all the clay accumulated in the tailings pond must be removed and solidified to the point that it could support heavy equipment traffic. [CERA Growth in the Canadian Oil Sands, 2009] These developments prove that the government is trying to prevent environmental damage and is taking the management of tailings ponds seriously. While the publicity surrounding the tailings ponds has been negative, they also play an important role in water conservation, as will be described in the next section.

4.4.3 Water Management

Oil sands operations, in particular from mining, are extremely water intensive and people are concerned that increased oil sands production will place too great a strain on the Athabasca river. In order to produce one barrel of bitumen from mined oil sands, it is estimated that 12 to 14 barrels of water are needed [CERA Growth in the Canadian Oil Sands, 2009], all of which is then pumped into the tailings ponds. Water from the tailings ponds is then reused in the separation process, reducing the need to draw freshwater from the Athabasca River. At present it is not possible to recycle 100% of the water from the tailings ponds. Out of the 12-14 barrels of water used to produce a barrel of bitumen, 8 to 10 barrels of water are recycled from the ponds with approximately 4 barrels of water stuck in the middle layer of the pond [CERA Growth in the Canadian Oil Sands, 2009]. The water that cannot be recycled must be drawn from the river, resulting in a net use of 4 barrels of fresh water for every barrel of bitumen. *In situ* production facilities require much less fresh water per barrel. Up to

95% of the water used to produce steam in SAGD operations is reused resulting in 1.3 barrels of additional water needed to produce 6.3 barrels of bitumen [NEB Canada's oil sands, 2006]. The total amount of fresh water which companies are allowed to remove from the Athabasca River fluctuates according to the flow of the river, during periods of low flow consumption is restricted to 1.3% of annual river flow [Government of Alberta, 2006]. This limit has not been a constraint on the oil companies who are currently consuming less water from the river than is currently allowed. The Government has approved companies to use a maximum of the 350 million cubic meters of water while present consumption amounts to 150 million cubic meters [Humphries, 2007]. Therefore, it appears that water consumption in oil sands production is sustainable and will not limit further production expansion. Furthermore, technological advances under development promise to drastically cut the use of water. Steam Assisted Gas Push (SAGP) is a new technology that is similar to SAGD except that it mixes non-condensable gas with the steam. This process is estimated to reduce steam consumption by 70% compared to SAGD [McColl, 2008]. Yet another new technique currently being researched is Solvent-Based Recovery Processes (VAPEX) which plan to recover bitumen using gaseous solvents thus eliminating the use of water and also potentially reducing GHG emissions by 85% [McColl, 2008]. The ability of industry to reduce water consumption in the face of government controls builds confidence that similar improvements can be made with other environmental issues, particularly with respect to the emission of Greenhouse Gases.

4.4.4 Greenhouse Gas Emissions

Greenhouse Gas (GHG) emissions are among the most contentious environmental issues in Canada with emissions from oil sands production of particular concern. A poll conducted by the Environmental Monitor in 2007 showed that global warming was the top environmental concern of Canadians [McAllister Opinion Research, 2007]. A clear majority, 62% of respondents, favoured stricter regulations for the oil and gas industry. These concerns are justified since Canada is among the world's ten largest emitters with total CO_2 emissions of 544,680 thousand metric tons in 2006 [UN Millennium Development Goals Indicators]. Although at this level Canadian emissions account for only 2% of total world emissions, far below countries such as

China, the United States, Russia and India (see Table 8), the numbers become far less complimentary when adjusted for population. As shown in Figure 41, Canada is behind only the United States in emissions per capita. A portion of emissions is undoubtedly a by-product from oil sands production, though not as significant as many Canadians believe. Oil sands production account for 5% of Canadian GHG emissions, 1/8th the level of emissions from the transportation sector, 1/4th from electricity and heat generation and half of the emissions from agriculture [Government of Alberta, 2006]. In response to public worries the industry has been researching new methods to reduce GHG intensity levels so that oil sands production will be viewed more favourably.

Table 8: Largest emitters of Carbon Dioxide (CO_2)

Country	CO2 Emissions (thousand metric tons)	Percentage of Total Global Emissions
1) China	6,103,493	21.5%
2) United States	5,752,289	20.2%
3) Russia	1,564,669	5.5%
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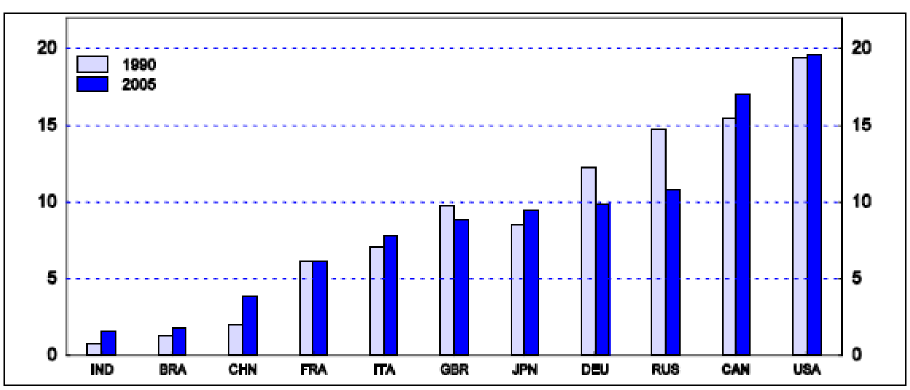
8) Canada	544,680	1.9%

Source: UN Millennium Development Goals Indicators

Figure 41: CO_2 emissions per capita

Tonnes of CO_2 per capita



Source: Mourougane, 2008

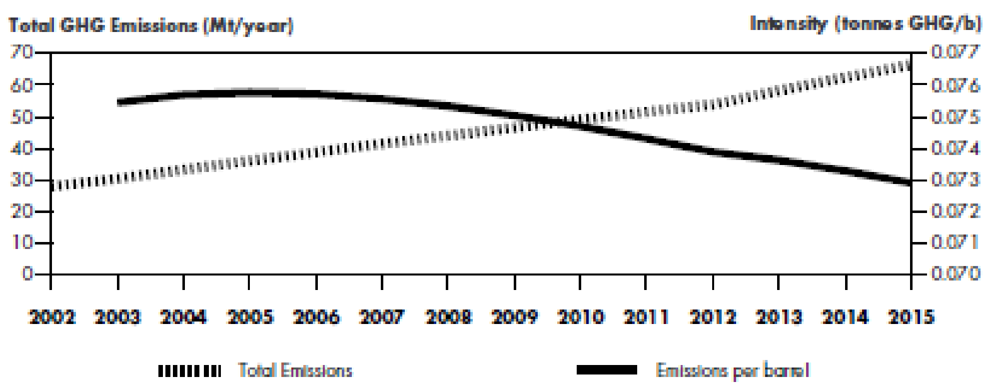
Oil production from the oil sands currently emits more carbon dioxide when compared to conventional oil production. Comparing well-to-retail pump[22] emissions from various oil sources shows that mined oil sands emit 1.3 times as much carbon dioxide as the average barrel of oil consumed in the United States while emissions from oil produced using SAGD are 1.7 times greater [CERA Growth in the Canadian Oil Sands, 2009]. For a comparison of emissions by oil source see Annex 4. Technological innovations promise to improve these emission rates and when combined with Carbon Capture Storage (CCS) technology it is believed that emissions from the production of oil sands will be equal or less than that of conventional oil [Government of Alberta, 2006]. Developments, such as Solvent Based Recovery Processes (VAPEX), have shown the potential to reduce CO_2 emissions by 85% compared to SAGD [McColl, 2008]. Further improvements to mining, SAGD and CSS will lower the amount of emissions per barrel as can be seen in Figure 42, while all new oil sands upgraders and *in situ* facilities that come online during and after 2012 will be required to adhere to more stringent CCS targets [Mourougane, 2008]. Despite the decrease in emission intensity, overall emissions are still projected to increase as oil production increases. Industry will need to better communicate with the public to show its determination to increase efficiencies and lower GHG emissions intensity. A 2009 poll commissioned by the Canadian Association of Petroleum Producers (CAPP) showed that 46% of Canadians think the oil companies have done a poor job balancing the environment and the economy [CBCNews, January 2009]. Part of the reason for this perception is that the oil industry has not communicated properly with the public, a fact acknowledged by the CAPP. The Federal Government must also be willing to force the oil sands industry to continue improving its environmental standards by including the oil and gas industry in future GHG reduction efforts. Environmental groups have already been attacking the Conservative Government, led by Prime Minister Stephen Harper, for its modest target of reducing GHG emissions in 2020 by only 20% from 2006 levels [CBCNews, December 2009]. The Federal government risks antagonizing environmental groups and the public by giving special exemptions to

[22] Well-to-retail pump emissions refers to the emissions generated from production, refining and transportation of oil

oil sands companies. These exemptions can only serve to reinforce the notion of oil sands production as being an extremely polluting industry and move public opinion against production expansion. The Government should set strict, yet achievable, targets for oil production in order to prove to its citizens that the oil industry is being held to the same pollution reduction standards as other economic sectors. If there is any good news it is that the CAPP poll found that 71% of respondents believed it was possible to balance successful development of the oil sands and environmental protection [CBCNews, January 2009]. It is now up to industry and the Provincial and Federal governments to prove the balance is possible. Should they be successful then the issue of GHG emissions will not constrain increased oil sands development.

The extraction of bitumen from the oil sands using SAGD or CSS has several significant advantages over mining. The first, and most obvious, advantage is that 80% of the oil sands are too far below the surface for open-pit mining. From an environmental standpoint however, *in situ* oil production is an improvement over mining because it has a much smaller footprint on the landscape; *in situ* processes only use approximately 15% of the land which would be disturbed by mines and do not produce tailings ponds [Government of Alberta, 2006]. Even *in situ* processes, however, disturb more land compared to conventional oil production. CERA estimates

Figure 42: Projected GHG Emissions from Oil Sands



Source: NEB, Canada's Oil Sands: Opportunities and Challenges to 2015 an update, 2006

that a typical SAGD project disturbs 6-7% of the leased land while a conventional project may disturb only 4% of the land [CERA Growth in the Canadian Oil Sands, 2009]. This greater disturbance is due to the fact that SAGD facilities, in order to generate sufficient steam and treat water, are larger than conventional facilities.

Furthermore SAGD facilities also require a large network of pipes which are often laid aboveground. Some environmentalists also fear that the forest will become increasingly fragmented as greater numbers of *in situ* facilities are built with wildlife populations suffering as a result.

4.5 Oil Production, Consumption and Export Projections to 2030

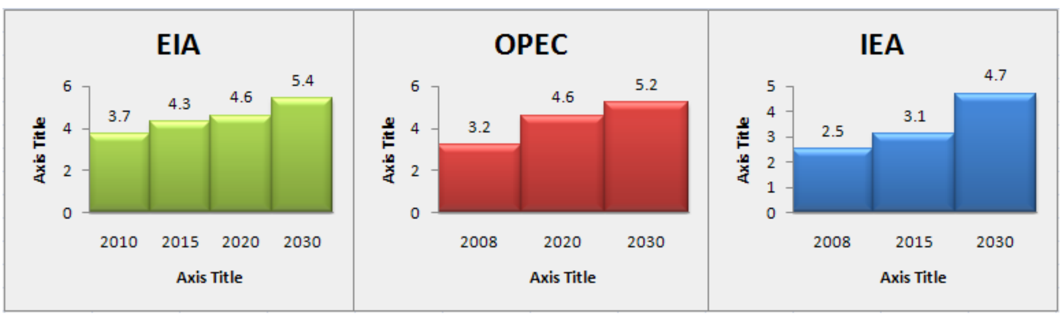
With a combined value of only 4 billion barrels, Canada's conventional oil deposits can no longer be depended upon to produce significant amounts of oil. The WCSB has already matured and has seen production decline at a rate of 3% per year, which is the rate of decline foreseen until 2020 [NEB 2009 Reference Case Scenario]. The offshore fields in Eastern Canada are also in a state of decline and without significant new discoveries it is assumed this trend will also continue. New discoveries are still being made and new project proposals have been submitted, however it is not expected that a significant discovery will be made that can reverse the decline. The NEB projects production in the WCSB to decline to a production level of 700,000 b/d by 2020 and offshore production to decline to 212,000 b/d over the same time period [NEB 2009 Reference Case Scenario]. Further recovery from these fields is expected to improve due to Enhanced Oil Recovery (EOR) technologies; however, the total amount of oil that can be extracted using EOR is estimated to total only 100 million barrels which is insufficient to alter future production expectations. As these older fields continue to decline, the only source remaining for expanded production is in the oil sands.

As opposed to conventional sources of oil, the oil sands are a very difficult and costly source of crude oil. In order to receive a 10% rate of return on investment the price of oil needs to be in the range of at least $60-$85 per barrel[23] [CERA Growth in the Canadian Oil Sands, 2009]. Investments in oil sands projects are, therefore, subject to change according to market price fluctuations and the overall economic situation. When the price of oil dropped from above $140 per barrel in July 2008 to $40 per barrel by December 2008, many planned investments were delayed. The result was a drop in industry capital spending from $20 billion in 2008 to $10 billion in 2009

[23] West Texas Intermediate (WTI) price

[CAPP, 2009]. The drop in capital spending will not impact current production but if investments continue to be delayed future oil sands expansion will be in jeopardy. According to the most current projections, sufficient investments will be made to enable oil sands production to increase up until the year 2030. Total Canadian oil production will increase to over 4 Mb/d by 2015 and approach 5.5 Mb/d by 2030, see Figure 43 for three different projections. The projections in Figure 43 are similar to the projections made by the NEB and CAPP. CAPP projects oil production reaching 4 Mb/d in 2020 and 4.17 Mb/d in 2025 the NEB projects 2020 production to be 3.8 Mb/d [CAPP, 2009 and NEB 2009 Reference Case Scenario]. The numbers calculated by CAPP and NEB do not include the production of refined petroleum products which would increase their estimates to levels comparable with the OPEC and EIA projections. The fact that so many industry projections show similar future estimates provides confidence that oil production of around 5 Mb/d will be attained by 2030.

Figure 43: Various Projections of Canadian Oil Production to 2030



Sources: EIA International Energy Outlook, 2009, OPEC World Oil Outlook 2009, IEA World Energy Outlook, 2009

In order to assess the likely volume of Canadian oil exports by 2030, projections of Canadian oil consumption must first be analyzed. Growth in Canadian oil consumption has historically been much slower than in the United States. Between 1980 and 2008 Canadian oil consumption increased from 1.87 Mb/d to 2.26 Mb/d [EIA International Energy Statistics], an average annual compound growth rate of 0.67%. Growth in Canadian oil consumption between 2008 and 2030 will be even slower; by 2020 consumption will be 2.3 Mb/d, close to present levels, and rise slightly to 2.4 Mb/d in 2025 and 2.5 Mb/d in 2030 [EIA International Energy Outlook, 2009]. At these projected levels, oil consumption would only grow by an average annual compound rate of 0.46%. The relatively flat rate of growth in future oil consumption implies that the virtually all oil production increases from the oil sands will be exported. Some Western Canadian crude will be sent to refineries in Eastern Canada to compensate for loses in production rates from Atlantic Canada, and oil exports to China may also increase. Once the Northern Gateway pipeline connecting the oil sands region to ports on the Pacific coast is completed, 525,000 barrels of oil per day will be available for overseas shipments [Northern Gateway Pipelines]. Of this total, it is expected that approximately 200,000 b/d will make it way to China while the rest can be shipped to other Asian markets or to the American West Coast [Guly, 2005]. It can therefore be expected that oil exports to the United States can potentially increase by nearly 2 Mb/d. This would translate into total Canadian oil exports to the United States reaching 4 Mb/d by 2030. By 2030 it has been estimated that American oil import requirements will be 8.49 Mb/d (see section 3.3.3), meaning Canada will potentially supply the United States with slightly less than half of their total required imports of oil. The oil industry is already preparing for this eventuality by planning to increase the current pipeline capacity. As previously mentioned the current pipeline infrastructure is reaching its maximum capacity however new pipelines and extensions of existing pipelines will begin to add capacity before 2010. TransCanada's Keystone pipeline is expected to begin sending oil to the United States in December 2009 with an initial capacity of 435,000 barrels per day before eventually reaching 590,000 barrels per day by late 2010 [TransCanada, Keystone Pipeline]. Enbridge is also working towards completing its Alberta Clipper pipeline which will ship oil to Wisconsin at a rate of 450,000 barrels per day by mid-2010 and have an ultimate capacity of 800,000 barrels per day [Enbridge, Alberta Clipper]. The sum of all current projects already under construction will add 2.22 Mb/d of potential pipeline capacity by the end of 2010, far ahead of an equal production output from the oil sands.

The consequence for American oil security from an increase in American oil import dependence on Canada is significant: American oil security will be greatly improved by relying on Canada. Canada is one of the most secure oil producing countries in the world due to a low level of threat from terrorist attacks on oil installations in addition to the fact that almost all oil shipments are done through pipelines [DeBard,2009]. Oil shipments by tankers are less secure compared with pipelines because they are subject to threats from piracy, geopolitics and adverse weather conditions. Pirates have targeted oil tankers on several occasions, most recently on December 30th, 2009 [The New York Times, Dec. 30, 2009]. Although that attack, in addition to another pirate attack of the coast of Benin [BBC News, Nov. 24, 2009], were unsuccessful in capturing the vessel, pirates did manage to hijack a Saudi oil tanker in 2008. The Sirius Star was hijacked off the coast of Somalia carrying 2 million barrels of Saudi oil, equal to more than a quarter of Saudi Arabian daily oil output [BBC News, Nov. 18, 2009]. These attacks prove oil tankers are vulnerable to piracy and can seriously disrupt oil exports. Oil shipments by sea can also be severely disrupted by geopolitics in the Strait of Hormuz. The strait is control by Iran, a country with whom many Western nations have very strained relations. Tankers leaving the ports in Iraq, Kuwait, Saudi Arabia and the United Arab Emirates must cross the Strait of Hormuz, through which approximately 40% of the world's oil is shipped [DeBard, 2009]. Should Iran close this strait for any reason, it would cause a severe disruption in oil shipments. Finally, pipelines are not affected by high winds, waves, and storms; weather events which can delay, damage, or even wreck, oil tankers. Furthermore, oil trade between Canada and the United States is protected by NAFTA, ensuring that Canadian politicians cannot threaten to withhold oil exports to the U.S. NAFTA guarantees that American political leaders will not need to worry about a supply disruption for almost half of their total oil imports in 2030, freeing them to concentrate on securing oil supply contracts from other nations.

CONCLUSION

The United States is currently one of the least oil secure countries in the world. Despite a constant decline in American domestic oil production since 1970, oil consumption has substantially increased over the past 40 years. As a result, the United States has been forced to rely on a growing volume of oil imports to make-up the gap between oil production and consumption. American oil security is negatively affected due to several factors, but the fact that the U.S. is the world's largest oil importer is the most important variable. In order to satisfy their demand for oil, the United States has no option but to rely on imports from countries in economically and politically unstable regions, including Iraq, Saudi Arabia, Nigeria, and Venezuela. Most oil producing nations are not concerned with American interests and may even try to harm the economic well-being of the United States through oil supply disruptions. American oil security is further affected due to the inherent dangers present in relying on oil shipments from overseas which can be disrupted due to geopolitics, piracy and weather conditions. It is clear that current American oil consumption and import levels continue to place the United States oil security in jeopardy.

Looking into the future, however, shows that American oil security will greatly improve. Projections reveal that growth of American oil consumption will remain relatively flat over the next 20 years while domestic oil production will receive a boost from oil extraction on the Outer Continental Shelf. These two factors will result in a modest decline of oil imports. The greatest oil security improvements, however, will come from increasing American oil supply dependence on Canada. Canada, one of the most secure oil producing countries in the world, is already the largest foreign oil supplier to the United States. Not only does Canada have a stable democracy and good foreign relations with the U.S., but they have a direct financial interest in the economic prosperity of the United States. Free trade between the two countries has deepened their level of economic integration while provisions included in NAFTA guarantee that the United States will receive a stable flow of Canadian crude oil and oil products. As Canadian oil production increases over the next 20 years, so too will their volume of exports to the United States. The larger volume of future oil exports will increase

Canada's share of total American oil imports from 19% in 2008 to nearly 50% by the year 2030. Canadian oil imports will thus displace a sizeable portion of oil imports from more volatile nations. Additional oil security gains will be realized due to the network of oil pipelines which link the neighbouring countries. Pipelines, unlike oil tankers, are not subject to disruptions from geopolitics, piracy, or adverse weather conditions. Several challenges must still be overcome, however. Development of the oil sands will require high levels of financial investment in order to increase capacity while the environmental impact from refining the oil sands must also be addressed by the Canadian government. The significant influence of oil on the American and Canadian economies, however, ensures that the two countries will work together to overcome any of these challenges. This spirit of cooperation will be financially advantageous for Canada, and will vastly improve American oil security.

ANNEX 1:

BTC Pipeline Route

Source: BBC News Sept. 17, 2002

Nabucco Pipeline route

Source: Nabucco Gas Pipeline Project

ANNEX 2

Calculation of Hubbert's Curve:

Hubbert's Curve begins with two considerations;

a) With a finite resource the production rate at time t=0 and t=∞ is equal to zero.

b) If there exists a single-valued function $y = f(x)$, then

$$\int_0^{x1} ydx = A \qquad (1)$$

where A is equal to the area between the curve $y = f(x)$ and the x-axis from the origin to the point x_1.

If the production curve is plotted against time then we have

$$P = dQ/dt \qquad (2)$$

where *dt* is the quantity of the resource produced at time *dt.*

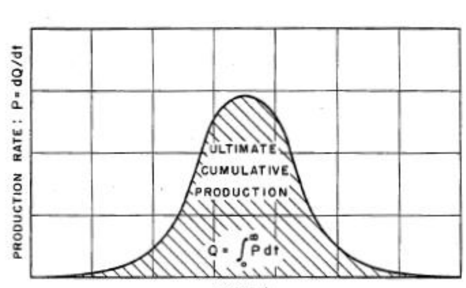
From equation (1) we see that the area under the curve to any point of time *t* is

$$A = \int_0^t Pdt = \int_0^t \left(\frac{dQ}{dt}\right) dt = Q \qquad (3)$$

Where Q is the cumulative production up to time *t*. Ultimate production will be given by

$$Q_{max} = \int_0^{\infty} Pdt$$

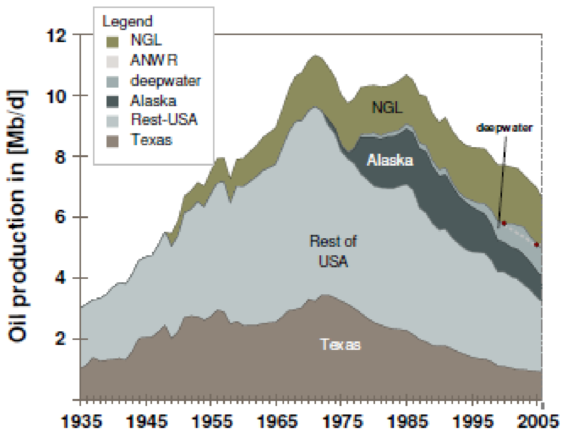
And will be represented on the graph of production versus time as the total area beneath the curve.

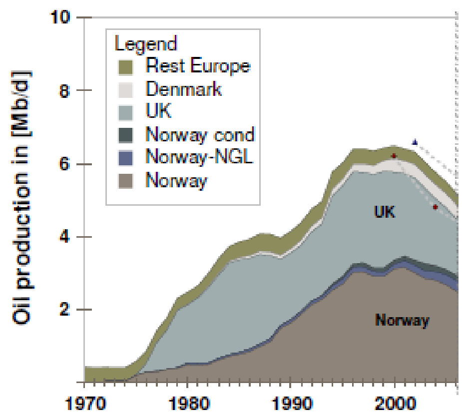


Source: Hubbert, 1956

Examples of bell-shaped curves in a mature oil regions:

Oil production in the United States (1935-200)   Oil Production in Europe (1970-2006)





Source: Energy Watch Group, *Crude Oil the Supply Outlook, 2007*

Top 20 Giant Oil Fields in the World

Field name	Country	Discovery year	Production start	Range of URR [Gb]
Ghawar	Saudi Arabia	1948	1951	66–150
Greater Burgan	Kuwait	1938	1945	32–75
Safaniya	Saudi Arabia	1951	1957	21–55
Rumaila North & South	Iraq	1953	1955	19–30
Bolivar Coastal	Venezuela	1917	1917	14–30
Samotlor	Russia	1961	1964	28
Kirkuk	Iraq	1927	1934	15–25
Berri	Saudi Arabia	1964	1967	10–25
Manifa	Saudi Arabia	1957	1964	11–23
Shaybah	Saudi Arabia	1968	1998	7–22
Zakum	Abu Dhabi	1964	1967	17–21
Cantarell	Mexico	1976	1979	11–20
Zuluf	Saudi Arabia	1965	1973	11–20
Abqaiq	Saudi Arabia	1941	1946	13–19
East Baghdad	Iraq	1979	1989	11–19
Daqing	China	1959	1962	13–18
Romashkino	Russia	1948	1949	17
Khurais	Saudi Arabia	1957	1963	13–19
Ahwaz	Iran	1958	1959	13–15
Gashsaran	Iran	1928	1939	12–14

Source: Robelius, 2007

ANNEX 3:

Sources of U.S. Oil Imports by Country (thousands of barrels per year)

Year	Imports from Canada	Imports from Mexico	Imports from Saudi Arabia	Imports from Venezuela
1993	328,504	314,961	467,753	368,641
1994	358,955	342,598	473,356	377,525
1995	379,518	374,719	459,826	419,996
1996	393,571	441,632	456,896	476,751
1997	437,396	496,275	472,093	508,730
1998	462,228	482,252	512,452	502,552
1999	429,962	457,655	506,272	419,893
2000	493,256	480,469	557,569	447,736
2001	494,796	508,715	588,075	471,243
2002	527,304	547,443	554,500	438,270
2003	565,533	572,572	629,820	431,704
2004	591,489	585,023	547,125	474,531
2005	596,183	567,955	527,287	452,914
2006	657,834	575,501	519,236	417,001
2007	689,209	514,124	528,189	419,180
2008	715,982	434,340	550,276	380,419

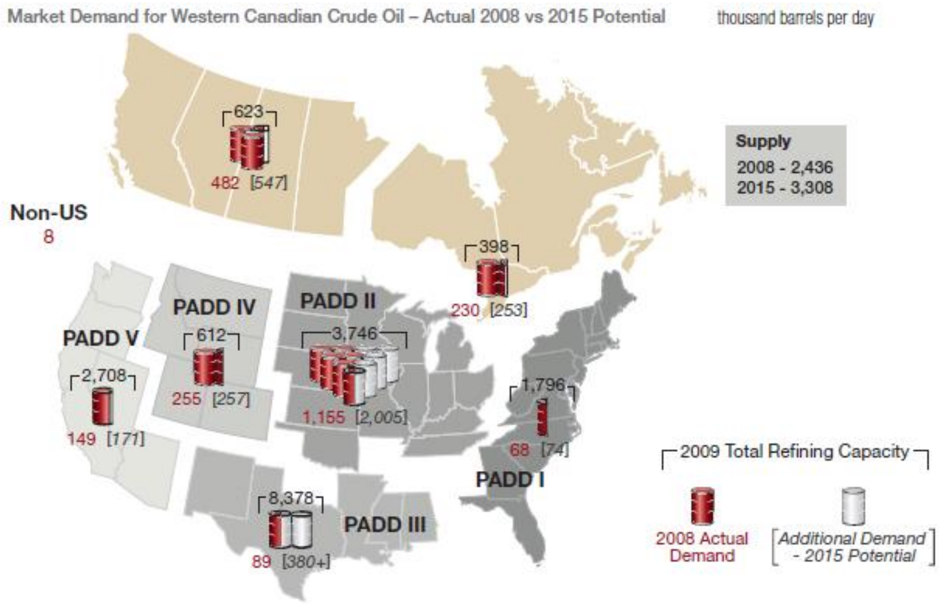
Source: EIA Petroleum Navigator

ANNEX 4:

Unprocessed oil sand

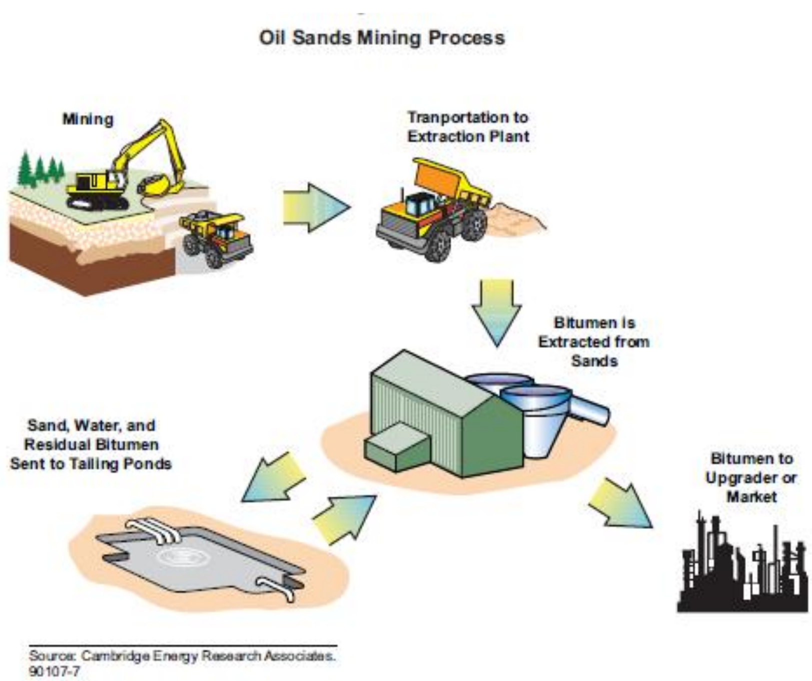
Source: http://blog.foreignpolicy.com/files/images/oilsand.jpg

Canadian Oil Exports to the United States by PADD



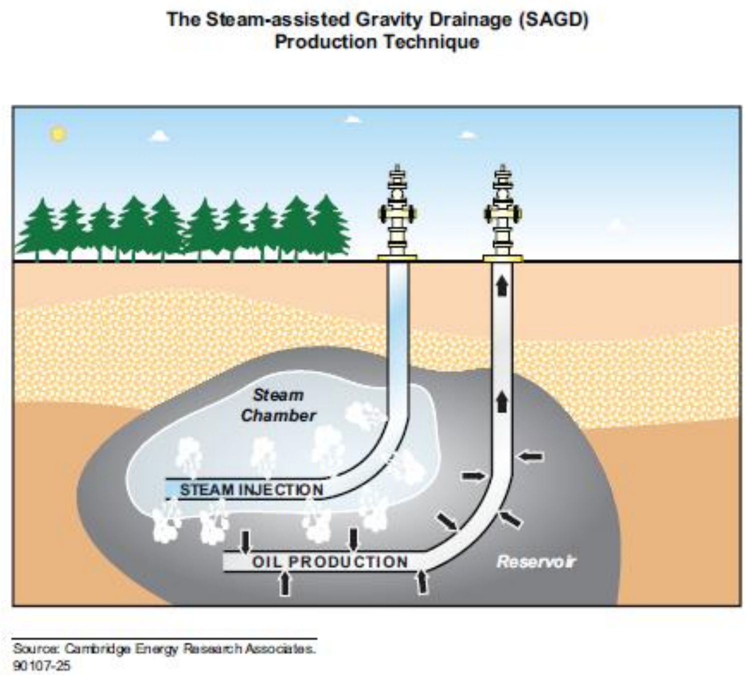
Source: CAPP, 2009

Oil Sands Open-pit Mining Process



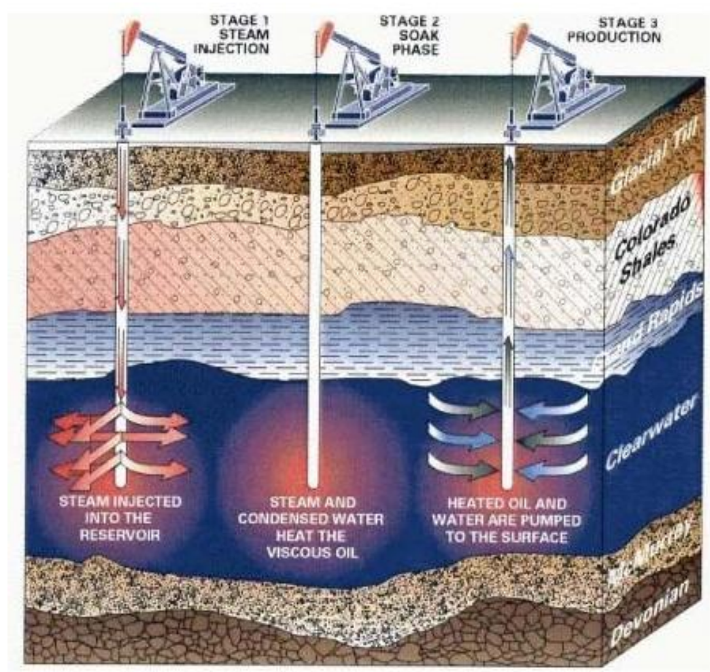
Source: CERA Growth in the Canadian Oil Sands, 2009

Steam Assisted Gravity Drainage (SAGD) extraction



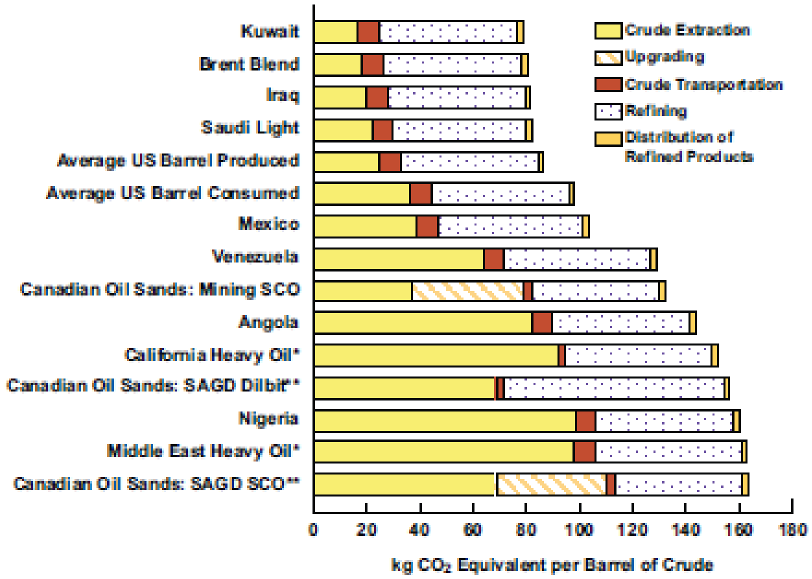
Source: CERA Growth in the Canadian Oil Sands, 2009

Cyclic Steam Stimulation (CSS) extraction



Source: http://www.ceaa.gc.ca/default.asp?lang=En&n=AFF9B551-1&toc=show&offset=8

Well-to-retail pump GHG emissions by source



Source: Cambridge Energy Research Associates.
*Assumes steam-assisted gravity is used for production.
**Assumes a steam-oil ratio of 3.
Data source: Collected from a range of published reports that include the reports listed below, industry sources, and other published reports.
DOE/NETL: "Development of Baseline Data and Analysis of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels," November 2008.
McCann and Associates: "Typical Heavy Crude and Bitumen Derivative Greenhouse Gas Life Cycles," November 2001.
RAND: "Unconventional Fossil-Based Fuels: Economic and Environmental Trade-Offs," 2008.
NEB: "Canadian Oil Sands: Opportunities and Challenges," 2006.
CAPP: "Environmental Challenges and Progress in Canada's Oil Sands," 2008.
GREET: Version 1.8b, September 2008.
GHGenius: 2007 Crude Oil Production Update, Version 3.8.
Syncrude: "2007 Sustainability Report."
Suncor: "2007 Report on Sustainability."
Shell: "The Shell Sustainability Report, 2006."
CERA/IHS data.
Report results were modified to represent a uniform system boundary and units.
When a single country is named, it represents an average country value.
90107-27

Source: CERA Growth in the Canadian Oil Sands, 2009

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